The University of Chicago

The Significance of the Dated Prehistory of Chetro Ketl
Chaco Cañon, New Mexico

A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE SOCIAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF ANTHROPOLOGY

1934

By

FLORENCE M. HAWLEY

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CHICAGO, ILLINOIS

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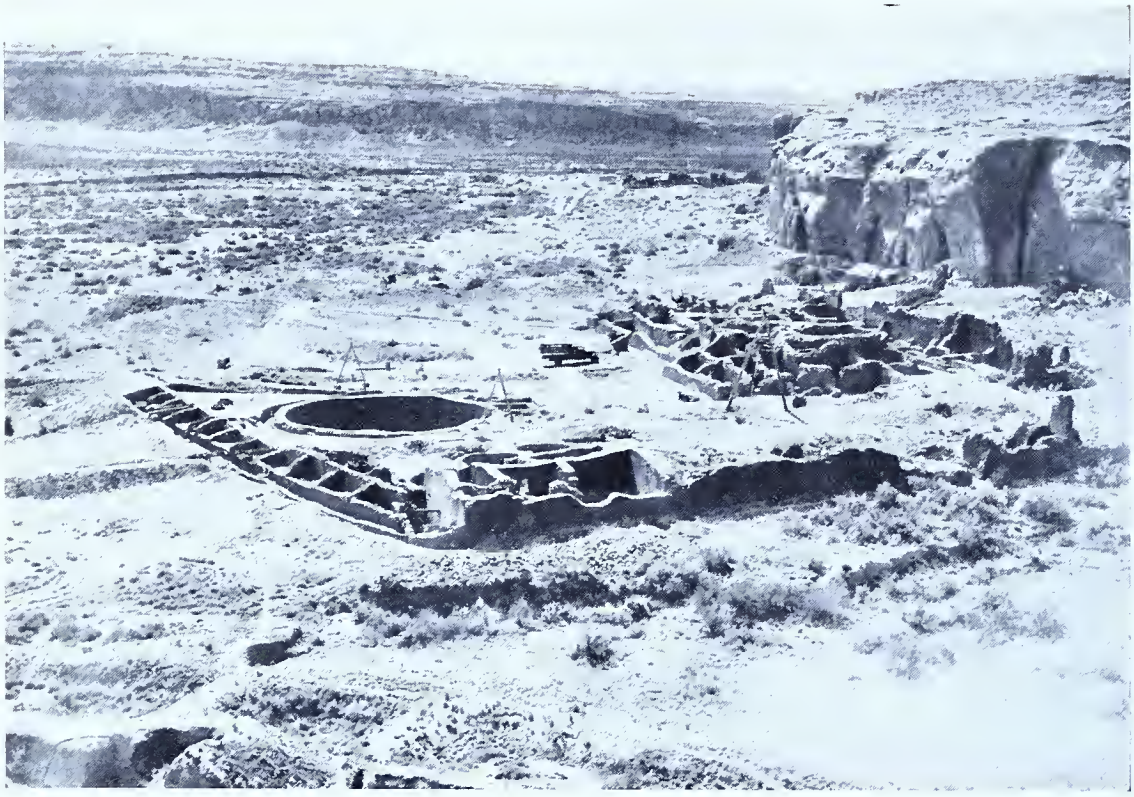

Chetro Ketl—1933

Talus House, Site 1, 1933

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Preface

For co-operation on the work of this paper I am especially indebted to the following individuals:

Dr. Edgar L. Hewett, who as Director of the School of American Research and of the Department of Anthropology, University of New Mexico, supplied all necessary funds and facilities.

Dr. A. E. Douglass, Director of the Steward Observatory, under whose direction and by whose method of tree ring analysis Chaco beam and charcoal specimens were dated. The resulting data were checked by him before being used and published herein.

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My chief assistant, Roy Lassetter, Jr., of the University of Arizona, who supervised collection and preparation of 250 beam specimens from Chaco pueblos during the seasons of 1930 and '31.

H. F. Davis, of the Steward Observatory, whose photographs and charts supplement this text with visual presentation of the data involved.

Mrs. G. Dewey, of the Tree Ring Laboratory, who assisted with statistical formulation of potsherd data from the refuse mound.

To these, to Dr. A. V. Kidder, Dr. F. W. Hodge, and Mr. H. S. Gladwin, whose support has been of material assistance, and to other friends whose aid in the field, in the laboratory, and in the preparation of this manuscript is not forgotten, I wish to express my appreciation.

And to my parents, whose interest in archaeology has provided practical assistance as well as stimulation in my own work, this paper is dedicated.

F. M. H.
1 9 3 4

Introduction

GENERAL SURVEY OF THE CHACO CULTURE AREA

For 800 years Chaco cañon in northwestern New Mexico, once the home of thousands of prehistoric American agriculturists, has been a desert occupied by none but nomadic Navajos and wandering bands from other tribes. Chetro Ketl, (Fig. 1, frontispiece), one of the largest of the fourteen large pueblos for which the Chaco is archaeologically famous, is the ruin of a communal structure of which four stories are still standing. The amount of fallen stone at the back wall indicates that a fifth story was originally present. Shaped roughly as a capital D, this pueblo once contained over 500 rooms and must have housed 1500 people or more. Pueblo Bonito, the famous neighboring ruin uncovered by Judd, is similar to Chetro Ketl in size and type, except that the curve of the D is made by the back wall of Bonito and by the front wall of Chetro Ketl. These are the only large pueblos yet excavated in the Chaco.

Location. Chaco cañon is a dry, sandstone, cliffed cañon, (Fig. 2, Plate 3), of northwestern New Mexico, 60 miles north of the Santa Fe railroad and 130 miles from Gallup, the nearest city. Both by drainage and by cultural affinity the region belongs to the San Juan area, which includes Mesa Verde in Colorado and Kayenta in Arizona. The Chaco pueblo group takes in some ruins which are out of the cañon proper. Over an area extending approximately 35 miles from Kinya-a near Crown Point on the south to Pueblo Alto on the north, and 20 miles from Pueblo Pintado on the northeast to Peñasco Blanco and Kinbiniola on the southwest, ruins marked by Chaco masonry and Chaco pottery are found located as close together as 200 feet or as far apart as several miles.

Geography. The area is known today as a desert. It is 6000 feet in altitude, watered by winter snows and by brief localized summer storms that fill the arroyos for a few hours and leave the uncovered land gashed and cut. A few junipers are scattered over the mesas, and hardy shrubs and dry grasses cling to the cañon floor, (Figs. 1, 2, Plate 2), and to the desert stretches outside cañon, (Fig. 1, Plate 3), but the deep dry wash which keeps the water table twenty feet below the surface in the Chaco drains away all moisture. This wash, (Fig. 2, Plate 2), so deepens and widens itself each year that parts of the pueblos have been destroyed. Others are threatened as the banks near them cave and collapse into storm waters swirling down from the continental divide 20 miles to the eastward. A

dozen cottonwoods could not be counted in those 20 miles of cañon, and of other trees there are only the red junipers of the mesas.

Types of Ruins. Three main types of ruins are known in the Chaco: pit houses, talus houses and single rooms, and the great communal dwellings. Concerning the first group two reports are available, one on two pit houses uncovered when Judd was working at Pueblo Bonito,[1] and one on Shabikéschee village, a pit house site some 11 miles up the cañon, excavated and studied by Roberts.[2]

Nothing has been published on the talus houses. Along the bases of the cliffs that rim the Chaco, as well as over the desert to the south, are discovered potsherd areas and mounds of varying heights showing remains of broken walls. Seven miles east of Chetro Ketl the cliffs break down into talus slopes high above the cañon floor; the rim of cliffs is lined by a row of one story rooms. Here and there in the cliffs, one finds small caves walled up to form rooms which may have served for storage or perhaps for dimunitive dwellings. Between the boulders that have broken from the cliffs are crannies inclosed with crude masonry, storage places which even now hide a few prehistoric corn cobs among the dusty accumulations of refuse. Whether all of these relics of ancient occupation belong to the period of the large pueblos we can not say; the one talus site behind Chetro Ketl and the one cave room, both dated through study of charcoal by the Douglass method of tree ring analysis, do fall into that period.

Fourteen large Chaco pueblos are known and named. Chetro Ketl. Pueblo Bonito, Peñasco Blanco, Kinbiniola, Pueblo Alto, and Pueblo del Arroyo are the most extensive; Kinya-a, Hungo Pavi, and Una Vida are smaller; and Kinklizin, Kinklitso (Yellow House), Wijiji, and Casa Chiquita are the smallest. Casa Rinconada, located on the south side of the canon just southwest of Chetro Ketl, consists of one large kiva surrounded with a few rooms which may have been used for dwellings. This site appears to have been more a religious center than a village.

Relation of Chaco Culture to Others of the San Juan.

Pueblos of the Chaco were contemporaneous with those of Mesa Verde and earlier in period than Kitsil and Betatakin, comparable structures of the Segi, although all three groups represent the late prehistoric period which is designated as Pueblo III in the Pecos classification. The dates of Mesa Verde, of the Segi pueblos, and of Pueblo Bonito and Pueblo del Arroyo as worked out by Douglass,[3] and the dates on the other Chaco pueblos as worked out by myself are charted in Fig. 2, Plate 1. This shows

1. Judd, 1924.
2. Roberts, 1929.
3. Douglass, 1929.

relative periods of construction. Although the large Chaco pueblos were begun at different times, all of them were inhabited during the 11th century and were deserted during the latter part of that century or in the first quarter of the 12th. Consideration of the combined living accommodations of them all gives us a rough estimate of prehistoric Chaco population as around 10,000.

Explorations and Investigation in the Chaco since 1776.

The pueblos of the Chaco were early remarked by explorers entering the area and later were among the first sites examined when American archaeologists of the late 19th century began to turn their attention to the southwestern field. Descriptions of the ruins and of the cañon as seen in the past provide data of value to those now attempting a hypothetical reconstruction of former conditions in the Chaco. A brief historical review of the Chaco since the Spanish period may be cited for reference.

The introduction to Pepper's report [4] presents a compilation of early references to the Chaco from which we may borrow a few important notes.

Bandelier [5] credits the explorer, Mier y Pachecho, as the European discoverer of the Chaco. His visit is dated as 1776, but documents dealing with the journey are yet to be located.

Gregg [6] made reference to Pueblo Bonito in 1844, his observations having covered the period of eight years just previous to that date.

In 1849 Governor Washington of New Mexico made an expedition into the cañon, and Lieutenant Simpson, the historian of the expedition, first put into print the name Chaco,[7] of whose origin or derivation no one is sure. Pueblo Bonito, Chetro Ketl, Wijiji, Hungo Pavi, and others of the ruined pueblos are mentioned in this report.

Holmes and Jackson mapped, photographed, and described Chaco ruins in 1877,[8] and their greatest service being in dispelling some of the mystery hitherto shrouding the pueblos. These men recognized the ruins as homes of Indians ancestral to the modern pueblo dwellers of the southwest. On Jackson's map of the Chaco [9] appeared a side sketch of the three masonry types he noted in the standing buildings. Of his types, "number I" corresponds with "type I" as later described by Judd and as used in the body of this present paper; "number II" corresponds to "type III," and "number III" corresponds to "type IV."

The first archaeological work attempted in the Chaco was that of the Hyde Expedition, which, under the personal direction of Dr. Pepper,

4. Pepper, 1920.
5. Bandelier, 1893, p. 253.
6. Gregg, 1851, p. 285.
7. Simpson, 1850.
8. Jackson, 1878.
9. Reprinted in Pepper's *Pueblo Bonito*, 1920.

excavated parts of Pueblo Bonito during the period of six years between 1896 and 1902.[10] Pepper's report included a description of the brief investigation by Nelson and Roberts [11] of two Bonito refuse mounds. Their work resulted in one negative and one positive piece of data which are of considerable interest here, inasmuch as our work on the Chetro Ketl dump was complicated by similar circumstances: no definite and limited pottery sequence was apparent, and the mounds were found to consist of rock and adobe building refuse as well as of sweepings from the homes.

In 1902 Hewett carried on some mapping of the cañon, and in 1919, '20, and '21 he directed the first excavations of Chetro Ketl, the first ruin east of Bonito.[12] Work was resumed on this pueblo in 1929, sponsored by the School of American Research and the State of New Mexico and under the direction of Hewett. Excavations are now being pushed forward during the three summer months of each season.

Between 1922 and 1927, Judd, under the auspices of the National Geographic Society excavated, repaired, and studied Pueblo Bonito,[13] which had been proclaimed a national monument by President Theodore Roosevelt in 1907. Beams from the village were turned over to Douglass of the University of Arizona for dating.

PROBLEMS AND TECHNIQUES AT CHETRO KETL

European feudalism and the rise of many of these communistic Chaco pueblos were contemporaneous developments of the 9th century A. D. During the 11th century when the Chaco pueblos were enjoying the peak of their material cultural development and architectural expansion, William the Conqueror was subjugating England, and small kingdoms were being set up in France and Spain.

The prehistoric southwestern pueblo area included most of Arizona, New Mexico, and the borders of neighboring states. By the time the first Spaniards reached this region, however, the prehistoric area had shrunk to include no more than 66 villages: Hopi in northern Arizona, Zuni in northwestern New Mexico, and the Rio Grande group of pueblos in north central New Mexico. The causes of this apparent tendency toward disappearance of the culture are not known definitely. Individual histories of sufficiently diverse and numerous pueblos should offer strong leads on the problem. Our present interest concentrates on the dated material culture sequences of architecture and pottery in Chetro Ketl, supported by what we are able to learn from other Chaco pueblos, excavated or unexcavated.

10. Pepper, *Ibid.*
11. Nelson, *Notes on Pueblo Bonito*, Pepper, 1920.
12. Hewett, 1921, 1922.
13. Judd, 1925, 1926, 1927, 1928.

Records of travelers and of scientists may be conned for supplementary data, but our most important material is that left by the prehistoric people themselves. In view of the inherent difficulty of accurately reconstructing the history of any dead cultural unit from material remains alone, the rigor of techniques introduced in this problem is a matter of primary importance. Two major techniques are being applied in this study: (1) exact prehistoric chronology and records of climatic variations obtained through the Douglass system of tree ring analysis; (2) supplementary relative dating apparent in superposition of masonry styles, stratification of the trash mound, and cross finds of pottery.

In this paper Part I will deal with dated masonry sequences and building periods. Part II will consider the classification of Chetro Ketl pottery, its successive periods of development determined first through statistical study of sherds taken from the east trash mound, and the later verification of the sequence and dating of the strata by means of analysis of ring records in charred remains of firewood taken from those strata. From examination of the resulting data one may distinguish periods when old debris accumulations were moved and re-deposited on the east dump in strata superposed over contemporaneous material. The significance of the sequences obtained from architecture and from the dump in indicating periods of varying energy within the pueblo, the subject of weather conditions in the Chaco, the effect of weather on building operations and on any forest that might have existed in the region, and the possible role of forest and of weather in the rise, decline, and disappearance of the inhabitants of Chetro Ketl make up the concluding discussion, Part III.

The present study is seen to concentrate on problems concerning the history of a single typical large Chaco pueblo. Solution of these problems is seen to rest fundamentally upon application of the Douglass system of tree ring dating and climatic study, as all data used either have been made available through that technique or have been re-examined in connection with dated material.

The accuracy of the tree ring technique, as subsequently discussed, provides the highest exactitude possible in chronology. As no more than one half the large pueblo of Chetro Ketl is yet uncovered, definite dates for the beginning and end of building periods can not yet be given. Some modification of the maps of periodic Chetro Ketl expansion may become necessary when excavation is completed. This paper must necessarily be left incomplete until some years hence when the rest of this material is available. At that time we expect to present in a final paper the remaining Chetro Ketl dates, revised data on maps, building periods, and architectural sequences, and to modify, if necessary, any statements herein incorporated.

PART I

Chetro Ketl Masonry Sequences and Building Periods

In Chetro Ketl the most obvious material to be studied for establishment of prehistoric sequence is masonry. Examination indicates that the structure is made up of sandstone ashlar masonry of at least five different styles or types. The presence in this pueblo of one additional type of construction, type I, is considered probable for reasons to be discussed later; it has not yet been definitely identified here, but no more than one half the excavation of Chetro Ketl has been completed.

The existence of several distinct masonry types in one pueblo poses at once some basis for solution of the problem of Chetro Ketl building periods. But, further, the diversity of types of structure offers an admirable index of cultural trends which assume value through their accurately dated chronology. The regularity in shape of the whole indicates that at least the last builders worked by a more or less preconceived plan. That the pueblo was originally intended to extend itself according to the ground plan seen today does not follow as a necessary corollary, however. In any one period architectural activities are found to have consisted of razing and reconstructing to a new plan some old sections of the pueblo even while other sections were being newly laid.

MASONRY TYPES

The six masonry types, which we have just mentioned, may be characterized as follows:

Masonry Type I. Roughly and irregularly shaped sandstone slabs are laid in an abundance of clay mortar to form a heavy wall approximately fifteen inches thick. The stone used came from the talus debris at the base of the sandstone cliffs, (Fig. 2, Plate 3). In contrast to types II, III, IV, and V, all of which consist of a rubble core with a stone facing, masonry I lacked a core. As seen in the cross section of an Una Vida wall, (Fig. 1, Plate 4), the sandstone slabs are laid from the two sides of the wall so that their inner ends roughly interlock. The surfaces of the wall are relatively even but not smooth. This type was previously described as "type I" by Jackson in 1877 and by Judd in 1928.

The double wall partially uncovered beneath the Great Sanctuary may prove to be of masonry I; it resembles this type more closely than any other.

Type II. This masonry consists of a rubble core covered with large slabs of sandstone laid in close courses and chinked around by very small spalls laid in a minimum of clay mortar, as illustrated in Fig. 3, Plate 4. Wall thickness averaged 18 inches; the rows of large slabs were separated by some 3 inches of spalls, each from ¼ to ½ inch thick. The technique of this masonry insured an attractive as well as an extremely strong and durable wall. The type is seen in many of the Chaco pueblos. Smoothness of surface, even width, the well-planned alignments of wall, narrow boards and small spalls are characteristic.

Type III. The third type of masonry is divided into two classes. We shall designate these as superior and inferior masonry III.

The superior type III masonry is the best to be found in the Chaco. Rows of large well-surfaced rectangular slabs were separated by bands of spalls somewhat larger than those used in type II. Comparison of the two types is shown in Fig. 2, Plate 4, the fourth floor of masonry III contrasting with the third floor masonry II wall over which the former was superposed.

The bands of spalls in masonry III average 1½ feet in thickness; the spalls themselves are from 1 to 1½ inches thick. In the best construction a single layer of even thinner spalls was laid directly beneath the succeeding single row of large blocks, shown in the detail photo, Fig. 4, Plate 4. As in type II, the stones were well shaped; the surface of type III was even smoother and the structure stronger than in type II.

In 1923 superior masonry III was described by Judd as "type III" in Pueblo Bonito.

The inferior type III masonry is banded in much the same manner as the superior type III, but a marked carelessness of workmanship is apparent. The bands are often uneven in width, varying from the horizontal. An example of the inferior type III masonry is found in the upper walls of the Great Sanctuary where it has been superposed over the superior masonry III of the lower bench and wall, Fig. 3, Plate 3. Its uneven construction shows even more clearly in the upper portion of Fig. 1, Plate 5, a photograph of the same wall but taken to show where it was later covered over with the very crude masonry VI, seen in the lower part of the photograph. Inferior masonry III walls lack the strength of the finer type of masonry III.

Type IV. The fourth type of masonry in Chetro Ketl has not before been described in the Chaco. It does not appear to have been present in all the

pueblos. In Chetro Ketl it consists of rows of brick-like blocks chinked with one or occasionally with two rows of small spalls, many of which have since fallen out in exposed areas; see masonry IV, Plate 9. There is no banding. In Pueblo Alto the same construction is found, (Fig. 2, Plate 5), but at Kinya-a the masonry which has been dated as of the same period and which is more similar to type IV than to any other type shows a smooth surface but a marked irregularity in the size of blocks, (Fig. 3, Plate 5). Spalls were of the same thickness as those used at Chetro Ketl and Pueblo Alto, but in contrast with the large blocks they appear somewhat smaller.

Type V. Masonry V, comparable to that described by Judd for Pueblo Bonito as type IV, shows thin slabs of more or less rectangular shape laid up without any spalls whatsoever. Fig. 4, Plate 5 shows it superposed over masonry II in the east wall of Chetro Ketl. (It may be noted that the masonry II has in this case lost most of its spalls, as is commonly the case in exposed portions.) Masonry V sometimes lapses for a few feet into what resembles inferior type III banded masonry, but as a type it is without bands. The wall surface is pleasing to the eye, but the structure lacks the strength of the previously described types.

Type VI. This last type is the crudest of the group, not excepting type I. It is difficult to believe that it was laid up by the people who were responsible for the fine workmanship of the other types. The kiva bench shown in the lower part of Fig. 1, Plate 5, illustrates type VI, which marks the nadir of Chetro Ketl constructive ability as certainly as the fine type III marks the zenith. Thick, crudely shaped sandstone blocks are laid up without core, without banding, without spalls, without any attempt to insure strength or durability. Masonry VI may be distinguished from masonry I by the thickness and shortness of its blocks, which contrast with the long thin slabs of the latter. It is conceivable that some examples not strictly typical of either might be found and confused if dating by tree ring analysis or by superposition were unobtainable. The type VI construction resembles the stone walls of some modern Navajo hogans, but the fact that in Chetro Ketl it was used as a final lining of two kiva benches convinces us that a pueblo people and not Navajos or other nomads were responsible for the type. None but pueblo people are known to have used kivas.

DATING TECHNIQUES

Two techniques for dating masonry were applied at Chetro Ketl and at the other Chaco pueblos examined for additional data:

(1) superposition of masonry types;

(2) application of the Douglass method of tree ring analysis to obtain exact dating of ceiling beams and of tie logs embedded in the walls.

Superposition. Dating by superposition requires no explanation except that the results to be obtained, while in themselves but a relative chronology of masonry types, may be used to supplement and check the dated types.

The technique of tree ring analysis is as yet so little known among archaeologists and withal so important in our field that a word regarding its history and application may be of value in comprehension of the data to follow.

Douglass Method of Tree Ring Analysis.

History. Early in 1901 A. E. Douglass, in seeking data on the periodicity and possible cyclic influences of sun spots, conceived the idea that if sun spots affected terrestial weather, trees which show in their ring width reaction to climatic variation should carry corroboration of sun spot periodicity. It had been shown that the rings of trees dependent on annual rainfall varied in relative width in proportion to the relative amount of soil water available. As trees growing beside water courses are always equally provided with moisture, their rings would show little variation from year to year; but trees on slopes or distant from water would show a succession of variations of ring width indicating annual weather conditions. Such ring records are designated as "sensitive"; those which show little variation are known as "complacent."

In the evergreen trees such as pine, piñon, Douglas fir, juniper, and the sequoias, one ring is laid down by the tree during the growing period of one year. In the late summer the tree adds a protective layer of heavy red material outside its white spring growth and then remains quiescent for the winter. False rings, which can be detected microscopically, appear when the precipitation of the previous winter has not been sufficient to keep the tree growing throughout the summer. The tree starts to lay up its red protective layer, and if no heavy summer storms appear to remedy the soil water deficiency, the ring will be completed but narrow. If rains do come, however, the tree starts to add another section of white growth before it lays down the final red covering at the end of the season. The red midline which marks the false ring is somewhat fuzzy on the exterior; the final red line which marks the edge of the completed ring is firm and smooth. Specimens which show many double rings, specimens which come from ridges where water is so scarce that the tree misses rings whenever the season is dry, and specimens which show ring deformation from injury of any sort are disregarded for tree ring dating as being undependable in record.

It was known that the cross section of a tree trunk presented a pattern of rings of varying widths. No one before Douglass, however, had recognized that if the relation of their relative widths could be correlated to rainfall records and thus proven to be dependent on weather, climatic rec-

ords could be obtained from ring records that might be carried indefinitely beyond the modern rainfall charts.

Exact dating of modern specimens, ring by ring, was established by Douglass in 1913. The reliability of all tree ring dating and of all tree ring climatic records rests primarily on the determination that specimens from a definable area may be cross dated; the record of any one is identifiable in the record of any other one of the same period. The process of cross dating is illustrated in Fig. 1, Plate 6, in which a series of pine specimens taken from various Chaco ruins are so mounted that lines drawn from one to another point out characteristic rings. These are immediately identifiable in the pattern they make up in each specimen; although their *actual* width measurement may vary in every piece of wood, the *relative* width of the rings in the pattern remains constant.

Groups of specimens from southwestern trees scattered over large areas were compared by Douglass. It became clear that one weather area extended from near the Rio Grande on the east to the western edge of northern Arizona and from central Arizona on the south to southern Utah and Colorado on the north. The sequoia district of northern California showed an extension of the general area, with some recognizable variations, and the Rio Grande, while necessitating a detailed chronology of its own, is being found by Stallings [14] to check in general with the main area. Specimens from mountains in southern New Mexico recently examined by Lassetter,[15] and others from mountains of northern Mexico examined by myself suggest an extension of the same general weather conditions southward, but sufficient data have not yet been obtained to make statements concerning these areas of isolated ranges, "island mountains" with assurance.

After the uniformity of records of living pines had been established, Douglass bent his efforts toward extending into the past the chronology he obtained from living trees. This required matching the pattern or ring configuration of rings at the inside of one tree with the configuration found toward the outside of a tree which had grown previously. The inner configuration of the second was then carried over to the outer rings of a third; this is carried as far as records are available. For these older trees he went to the Hopi pueblos known to have been in continual process of construction and habitation since pre-Spanish times. From these he went to the ancient pueblos.

The patterns of the ring record are set upon coordinate paper in the form of a chart in which each mark represents the mean of the characteristic relative variations of one ring from the observed average width of

14. Stallings, W. S., 1933.
15. Lassetter, R., (unpublished).

the group of surrrounding rings. Comparison of each ring to its immediate group is made necessary by the characteristic decrease in ring size from the center of the tree to the exterior, dependent on decrease in acceleration of growth due to age. Variations in total average ring size between specimens growing near or far from a water supply are similarly adjusted. On the strip of coordinate paper the right end represents the current year; the left extends back into past time. It is necessary to keep a record of each typical variation in the sequence. As it became obvious that the narrow rings representing the dry years were more important as characterizations of sequences than the larger rings indicating unusually damp years, the dry years were marked with long lines. The length of the line extending vertically up the paper is inversely proportional to the narrowness of the ring seen in the tree. Extremely small rings are marked with a long line; a wider ring is represented by a shorter line; an average size ring is not marked on the paper at all, and a very large ring is marked with a B. Charts of hundreds of individual trees are matched against each other, and a general chart representing actual climatic variations in the area is derived from the average of the diameter of all rings in each year through the entire group.

The charts of individual pieces, matched together and thereby cross dated, are illustrated on a small scale in Fig. 2, Plate 1. The master chart obtained, ring by ring, by averaging the lengths of lines representing each ring on the individual charts, is shown at the bottom of the figure. Where a number of long lines occur close together, it is obvious that a number of dry years are represented; such a drought period is usually marked by a wavy line extending over all the chart "years" affected. The individual records shown in this illustration are some of a group of prehistoric piñon charts from charcoal pieces once burned as firewood in Chetro Ketl and thrown out upon the dump. Our master chart obtained from them is the first dealing with a piñon record in this part of the prehistoric period; with minor variations it is found to check closely on the pine chart for the same period.

No sequence of rings has ever been found to repeat itself exactly in a pattern; this point is of primary importance in dating specimens. The work of Douglass and his associates each year extends the master chart still farther into the past. In 1932 the inner rings of the kiva pilaster support, C. K. 331, taken from Kiva G in Chetro Ketl, (Plate 8, and Fig. 6, Plate 9), were found to carry the record back to 643 A. D. This was almost a hundred years beyond the count previously known with certainty. Since then material has been obtained from other districts, which, when all the points are adequately checked by Douglass in comparing a number of specimens, should carry the general record several hundred years farther into

the past. Every part of the master chart is checked and re-checked through examination of hundreds of specimens before it is considered verified and established. It is necessary to emphasize the manner of derivation of the master chart in view of the many inquiries which have come to us regarding its validity.

Archaeological Application of Tree Ring Dating. Where beams have been preserved in the southwestern prehistoric pueblos of the climatic region covered by the master chart, their sequences may be dated. That date determines the age of the wall in which the beam is embedded. Because of the clear records they carry, pine, Douglas fir, and piñon are the woods on which tree ring dating has hitherto depended in the southwest; fortunately these were the woods most commonly used in ceiling construction in the pueblos of the central and northern portions of the pueblo area. Juniper carries a record considerably more erratic than these others, but a few specimens show sequences immediately identifiable with certainty. Such a piece is U. V. 24, (Fig. 2, Plate 7), the record of which is as distinctive as the pine record of C. K. 373.

Little work has ever been done on the various species of juniper. Douglass has dated some pieces, and in the summer of 1933, sponsored by the National Geographic Society and under the direction of Douglass, I put in some time studying a collection of large full section specimens. The results of this work may be briefly summarized in the statement that only about 12% could be dated with certainty. Others yielded probable dates that might be verified with further development of technique and familiarity with the type of rings characteristic of this wood. There is little doubt that in the future junipers will be used to date ruins, although it is not likely that we shall find them datable in as large percentages as pine or piñon. Cottonwood and other trees of that type were used for beams of some pueblos located near water courses, but these woods are of no value for dating; the vague ring markings and location near water make them unsuitable for such work.

In our Chaco work 565 specimens were collected and examined. Of these 263 were Chetro Ketl beams, 200 were pieces of charcoal from ancient firewood in the Chetro Ketl dump, and 102 were beams in exposed walls in other Chaco pueblos. Data on this material appear in the protocol I of the present paper.

Collection and Preparation of Specimens. Beam specimens are sawed from the ends of beams only if those beams have fallen from a decayed roof or if they are of great chronological importance and may not, for various reasons, be obtained by use of the tubular borer. This borer, developed by Douglass, consists of a metal tube with saw teeth at one end and a shaft

which fits into the jaws of a brace at the other. In using it, a thin starting plate, (Fig. 1, Plate 9), pierced with an aperture the size of the borer is first nailed to the log. As one bores through this aperture, (Fig. 2, Plate 9), the plate prevents the borer from slipping from side to side before it takes hold; slipping crushes off the outer rings. The core which is removed, (Fig. 3, Plate 9), is a beam radius on which the rings lie transversely.

The surface is prepared for microscopic examination with a razor blade cut, and the date determined through comparison of the individual record with that of the master chart. If the last ring of the tree is present, its date gives the cutting date of the beam; the season of year in which it was cut may be seen through the relative degree of completion of growth in the last ring.

Charcoal specimens show as fine a record as do unburned trees, but the surface must be chipped or broken rather than shaved before it can be read. Decayed wood, if not in a powdery state, is preserved and prepared for study by being immersed in a saturated solution of paraffin in kerosene. Both charcoal and decayed wood specimens are frequently found to have lost their outer rings. This situation is apparent when the margin of the outer ring is seen to be incomplete, or the relative width and curve of the last rings present do not indicate an exterior, or there is no sign of bark present, etc. Extreme caution and long familiarity with ring types is necessary in making estimates as to the approximate number of rings lost from the exterior; dates on specimens for which such an estimation must be made are so marked.

Accuracy of Results. As the study on each specimen is completed, the certainty of the date obtained is evaluated and graded in order to minimize any possibility of incorrect results. A perfect record gives a date which is graded as 10; an unquestioned date on a slightly poorer record is graded as 9; an unquestioned date on an ordinary record is graded as 8, specimens graded at 7 represent uncertain, although probable dates. No dates graded below 8 have been considered in this work on Chetro Ketl; moreover all have been re-checked more than once by myself, sometimes by other members of the laboratory force, and finally substantiated, group by group, by Douglass.

In collecting beams by which to date rooms or masonry, it is advisable to take a specimen of every piece of wood to be obtained, for it is found that ancient as well as modern pueblo people were accustomed to re-use old beams from razed structures side by side with those freshly cut for new buildings. Because of the re-use of logs in Chetro Ketl, it is necessary to examine and date every specimen available in a room. By comparing the dates of the group of specimens, one can usually tell the building date of a

room from the clustering of the results. Older specimens represent previous building periods, some of the structures of which were demolished and their materials re-used at the time the later construction was in process. Occasionally it appears to have been necessary to later replace some weakened beam with a new one; the dates of the beams in such a room will cluster around some year antecedent to that of the single replacement beam. The check of masonry types against beam dates and the check of dates taken from adjoining rooms of similar masonry type minimizes these difficulties. All the dates from one room are recorded and then charted, as in Plate XI, where the horizontal scale represents the number of specimens from one room dating in any one year. The wide range of dates from some Chetro Ketl rooms is notable, but when one examines the latest date obtained in all the rooms studied in one section and of one type of masonry, they are found to fall into close alignment.

CHETRO KETL BUILDING PERIODS

Chetro Ketl building dates range from 945 to 1116 A. D., according to results now in hand; future work may extend this range somewhat. The table of specimens, their dates, and the masonry types of rooms from which they were taken are included for reference in a protocol to this paper. In the chart of Chetro Ketl room dates, Plate XI, the masonry type of each dated room is represented by the figure listed at the right. The unusually difficult situation occasioned by the re-use of a great number of old beams becomes apparent when one notices the frequent wide range of dates on specimens from one room. With the exception of the occasional date from a replacement log, the latest cutting date obtained on logs from a room definitely determines the earliest date at which that room could have been constructed: the room could not have been constructed before the logs were cut. Replacement logs, which are rare, may be detected from the fact that dates on them are considerably later than any others from a room. The heavy beams used were not likely to require replacement until after long use, if at all.

The building dates fall into groups which mark the construction periods of this pueblo. An examination of dates indicates that one or more of the masonry types previously described are found to have been characteristic of each period. Three major building periods are to be recognized; a fourth is considered probable. Dates obtained from exposed logs in other Chaco pueblos indicate that these periods may not pertain to Chetro Ketl alone. This is a matter for further investigation.

First Period: Masonry I. (945-1030). No masonry of this type has yet been identified with certainty in Chetro Ketl, but the fact that we have re-used Chetro Ketl beams dating in the period during which masonry I is

known to have been used at other pueblos leads us to expect the future discovery of such masonry somewhere in parts of the pueblo yet unexcavated. The earliest log obtained from Chetro Ketl gives a cutting date of 945 A. D. Since this log came from the third floor ceiling of room 59, type II masonry, on which the other beams of that ceiling gave the building date of 1060, we must suppose that the older log was re-used in this room after having been salvaged from some demolished earlier structure. Other re-used logs found in type II masonry date 1000, 1002, 1007, 1008, 1009, and around 1020. That these are re-used timbers is indicated in each case by the large proportion of more recently cut beams built into the rooms containing the older specimens.

It is impossible, of course, to say just what type of masonry originally held these logs later re-used in masonry II, but we do have evidence that masonry I was the type used in other Chaco pueblos between the latter half of the 9th and the first quarter of the 11th centuries. The most ancient cutting date for any log yet known in the Chaco region is 861 A. D.[16] the year of the outer ring of a small beam found incorporated into a crude masonry I wall high in the central back section of Una Vida, (Fig. 7, Plate 9). Four poles built horizontally into this type of masonry in the southwestern corner of the same pueblo date at 950. A part of the west section of the central extension of living rooms at Kinbiniola is of the same masonry; the five specimens from it dated 941, 942, and 943. From masonry I at Peñasco Blanco come dates of 898, 915, 915, and 941, five specimens again having been dated. As no masonry II has been found to date before 1030, and as early dates have come consistently from masonry I in Chaco pueblos, the Chetro Ketl logs re-used in masonry II but dating in the period of masonry I point to a period of early construction at Chetro Ketl. As excavation goes on older walls are constantly being found under those of later periods; if walls of masonry I were built in this pueblo, it is probable that some definite trace of them will be found as excavation progresses. Until then the existence of this period of crude masonry construction at Chetro Ketl must remain hypothetical.

Second Period: Masonry II and III. (1030-1090). The second construction period at Chetro Ketl covers 60 years, according to dates so far obtained, during which the two types of masonry were used in succession. The two divisions of this period, characterized by the two types of masonry respectively, merged one into the other. We find the building to have been continuous; the latest dates of masonry II coming at 1065 while the earliest found for masonry III is 1062.

A. *Masonry II. 1030-1070.* The earliest construction period of

16. Data on all dated specimens may be found in protocol I of this paper.

which we now have definite evidence at Chetro Ketl is that of the second type of masonry—that of narrow bands of blocks separated and chinked around with small spalls. Fig. 1, Plate 12 tentatively maps the pueblo as our data indicate its reconstruction for this period; Fig. 2, Plate 12 shows the masonry II used in the work. The data on which this reconstruction is based consist of masonry dated by tree rings and of other pieces of masonry of the same type relatively dated in this period because of identity with that which has been found to date consistently in the period.

The date of 1030 for the beginning of this period comes from *re-used* logs in masonry II. The group begins at 1030, and continues without a break until 1070. It appears that since these dates are found to be closely continuous, one successive period of cutting timber and building is here represented. It is probable that the work did not follow a constant level of activity, but until the entire pueblo is excavated and dated, this question can not be answered. Structures were raised, and later, with some changed conception of the pueblo floor plan in mind, they were torn down and their material used again. This period is marked by a great amount of construction, and evidently, to judge by the re-used beams, of reconstruction.

The earliest building date yet taken *directly* from a masonry II room is 1035 A. D. The room is in talus site I, located against the cliff at the northwest corner of Chetro Ketl, (Fig. 2, Frontispiece.) The same date came from one of the logs later re-used in the southeast buttress of Kiva G.

The only room in the back section of Chetro Ketl yet excavated to the first floor is room 64, on which the three ceiling beams all date 1038. Other rooms in which the excavations will be carried to the first floor in the season 1934 may give some dates even earlier.

When first built the rooms of the back section were but two tiers deep, but before another story was added the outer wall was thickened on the back to hold the roof beams of another tier of rooms added to the rear of the first two. The exact date of addition of this tier can not be known until the first floor rooms are excavated. It evidently came before 1043 when the second floor of the back tier rooms 44, and 46 and 53, adjoining, were constructed.

Meanwhile, in 1037 the second floor of room 43 had been built; in 1038 the second floor of rooms 39, 40, and 49, all adjoining, had been constructed. In 1040 the second floor of rooms 42 and 58 were added in the middle tier. Some rooms of the second floor were built much later than others. In room 59, on the back tier, we find the second floor dating 1048, while the same floor of rooms 47 and 48 in the middle tier date 1054 and 1053, respectively. Although we have not the dates on this level of intervening rooms, it is apparent that the second floor growth was more or less intermittent and sectional as the population grew and required new living quarters.

The third floor of the back section evidently grew in something of the same irregular fashion. In 1051 rooms 39 and 57, in the front tier, added a third floor. In 1054 room 40, next to 39, likewise added another story. In 1057 room 43, in the middle tier, and in 1059 room 44, in the back tier raised third floors. Rooms 47 and 48 in the middle row, and rooms 54 and 59, adjoining, in the back row grew to three floors in 1060. Room 46, in the back tier, built a third floor in 1063; room 53, adjoining, built in 1065, and room 42, in the middle row, in 1070. The kiva of masonry II, directly in front of the three rows of living rooms, was evidently of this period. It was later filled in and covered over with kiva I. Nothing from it has been dated.

TABLE I

DATES ON CHETRO KETL ROOMS, MASONRY II.

Back Section of Pueblo.

Room No.	Fl.	Building date	Other logs cut from room	Repair logs	Re-used logs
24 b	1	1050 A. D.			
39	3	1051			
39	2	1038			
40	3	1054	1053 (2 beams), 1052		
40	2	1038	1037		
42	3	1070			
42	2	1040	1038		
43	3	1057	1052		
43	2	1037	1029, 1030, 1033,		
44	3	1059	1052, 1050, 1048, 1047	1000, 1002, 1007, 1008, 1009 (4 beams), 1020	
44	2	1043	1040, 1038		
46	3	1063	1061, 1052		1023, 1033
46	2	1043	1041		
47	3	1060			1037, 1038, 1039
47	2	1054			
48	3	1060	1059, 1052 (2 beams)		1030, 1038 (2 beams), 1039
49	2	1038			
50	3	1060			
53	3	1065			1050, 1047
53	2	1043	1042, 1040 (2 beams)		
55	1	1030+ (1020+ca. 10)			
54	3	1060+ (1050+ca. 10)			
57	3	1051			
58	2	1040			
59	3	1060			945
59	2	1048			
64	1	1038 (2 beams)			
48	2	1053 (5 beams)			
East Wing					
101	2	1050	1049		
102	2	1050			
103	2	1048± (1018+ca. 30)			1024

Little tree ring dating of masonry II rooms has been done in the east wing; excavations have been in the type III masonry of the southeast corner, and all but the upper edge of the type II is still underground. Room 101 was dated at 1050 through a section taken from the beam end shown in Fig. 4, Plate 5. The single specimen dated from room 103 was cut in 1024; it was probably a re-used log. The outer rooms of the east wing as far south as room 101 show the first floor to be one continuous piece of stonework of masonry II; the walls of the inner rooms are uncovered only in small sections, but these are of the same masonry.

The inclusion of the west wing on the tentative reconstruction map is justified by the following facts: a typical Chaco pueblo construction consists of a back section with two wings extending forward, and since the east wing shows its lower floor to have been of the period of masonry II, it is more probable than not that the west wing likewise belongs to the same period. Moreover, the general map of the ground plan of the pueblo as we see it today, (Plate 10), makes it apparent that the west wing was built up as a unit before its design was confused by later tangential additions.

If we accept the proposition that since all of this type of masonry thus far dated has fallen consistently into one period and that we can therefore tentatively give other masonry of that type a relative date through placing it in that same period, we are justified in including in the reconstruction map sections dated only by masonry types. Dotted lines on this map indicate areas in which the walls are covered but may be traced. Their masonry is not yet known and can be suggested only by analogy with neighboring or with parallel and symmetrical parts of the ruin. The danger inherent in such use of analogy is recognized. The "indirectly" dated sections of the map are admittedly tentative, and such regions must be understood as representing not more than a preliminary reconstruction from the data at hand, to be checked and revised, as necessary, after future excavations.

B. *Masonry III. (1062-1090).* The latter part of the second building period was the classic epoch of Chetro Ketl, the period of the finest masonry. It is obvious from dated beams taken from masonry II and masonry III, however, that between 1062 and 1070 the two types of construction overlapped. Such a situation is to be expected in transition from one style to another. The change was no more than widening the bands of spalls between the slabs and using larger and more symmetrically-shaped spalls. The best examples of type III masonry, (Fig. 5, Plate 12) represent the finest construction ever developed in Chetro Ketl, but a poorer grade of the same construction, (Fig. 5, Plate 12), was common. The latter is designated as "inferior type III" masonry; at least in some cases it

succeeded the superior type. Both the fine and the degenerate have been described in connection with *Masonry Types.*

Dates have not been obtained from as many rooms of masonry III as of masonry II, because of the lack of wood specimens. The type III masonry, being later, is largely above the other, and its beams have been more exposed to the weather and to vandals. Consequently several sections of masonry III structure in Chetro Ketl must be relatively dated by superposition and comparison with dated walls.

1. *Superior Masonry III.* The two best examples of fine masonry III are the lower benches of the Great Sanctuary and the side walls of the big kiva whose southeastern arc was uncovered beneath the later masonry, inferior type III and type IV, of kiva G and the rooms surrounding it. (See maps, Plate 10, and Fig. 3, Plate 12). In the Great Sanctuary the superior masonry III is known to precede the inferior masonry III because that latter type has been employed in the small upper bench which covers the fine superior type III bench beneath it.

It might be suggested that the large communal kiva found beneath Kiva G was constructed directly in front of the living quarters of the back central section as they appeared at the end of the period of masonry II. It appears that shortly after this kiva was finished, additions were made to the living rooms of the central section. This kiva was filled and rooms were built over it. Another great sanctuary was constructed for use far out in the plaza. The identity of the masonry of the filled-in kiva with that of the lower benches of the Great Sanctuary, and the superposition of inferior masonry III over each, points to their having been constructed within a short time of each other.

As indicated by the masonry, the fourth floor of the back section of the pueblo was added at about the same time. This presumably extended entirely across the back section; at present we can trace it over the rooms indicated by the solid line on the reconstructed map of additions made during this period, (Fig. 3, Plate 12). The beams which it once held have disappeared; we can date it therefore, only relatively.

In other Chaco pueblos the fine masonry III has been dated by beam specimens, and the dates are found to cluster around 1060. In Hungo Pavi, beams incorporated into masonry III walls were found to have been cut in 1059, 1063, and 1064. From Pueblo Pintado walls of this type came two beams dating 1060 and 1061. An excellent example of this type of masonry dated 1060 in Peñasco Blanco. These dates and the presence of the inferior type III masonry superposed over the fine type III work at Chetro Ketl lead us to place a general date of $1060\pm$ on the superior masonry III of Chetro Ketl.

2. *Inferior Masonry III.* The inferior type III masonry contained many logs which have been dated and are listed in table II. Unfortunately, but a few rooms are represented in the central and back sections of the pueblo; some rooms of this masonry have lost all beams and others appear to contain only re-used logs.

TABLE II

DATES ON CHETRO KETL ROOMS, MASONRY: INFERIOR TYPE III

Central and Back Section of Pueblo.

Room No.	Floor	Building date	Other logs cut from room	Repair logs	Re-used logs
Kiva I		1090 (4 beams)			
Kiva K		1099			
Room 64	4	1072			
East Wing					
1	1	1063		1102	1038, 1052
2	2	?			1037, 1038 1039, 1050
4	1	1063	1059, 1060, 1062	1080 1100	
8	1	1061 (2 beams)		1074	
8a	1	1061		1068	
Kiva A		1071 (3 beams)	1069		

Rooms 5, 6, and 7, which adjoin the rooms listed above and thereby extend the southern end of the east wing, are of the same type of masonry and consequently appear to have been added at the same period, although no material from them has been dated.

In the central section of the pueblo it is seen that three adjoining kivas, I, J, and K, were constructed in front of the line of living rooms. Kiva I was superposed over the older filled-in kiva of type II masonry in 1090. Kiva J, constructed of the same masonry, yielded a beautiful specimen of a kiva pilaster support in the form of a block with corners cut to right angles and sides polished to smoothness. The end within the wall had been ground off until it was smooth. Such woodwork is evidence of extraordinary care in construction of kivas. The woodwork indicated by the finish of this pilaster support is noticeably superior to the stone work of the wall into which it was incorporated. Unfortunately, in squaring such a block enough is cut from its exterior to prevent establishment of the cutting date of the log. The masonry of the kiva indicates that it was built about the same time as kiva I. In front of this section extended a large windowed corridor, the windows of which were later filled. The corridor was then divided into rooms.

In 1099 kiva K, the west tower kiva, was constructed. The rooms adjoining these kivas may belong to part of this period or entirely to the next period; the few dates have fallen into the latter. As inferior type III

masonry was used in both periods, it is difficult to limit the extent of additions in this period.

As indicated in Table I, rooms 2, 3, 4, 8, and 8a were added between 1060 and 1065. Rooms 1, 5, 7, and 9, which adjoin and thus extend the southern end of the east wing, are of the same masonry and appear to have been constructed at about the same time. Some time before rooms 8 and 9 were added, at least the southern end of the second floor of the outer wall was constructed of inferior type III masonry, which sometimes is almost entirely lacking in the characteristic banding. What may be seen of the eastern end of the back wall seems to be a part of the same construction. A double curved wall was added to connect the two wings of the pueblo and so to inclose the plaza. Later the space between the walls was filled in, and a row of one story rooms was built across and on top of them; these are of poor masonry III but have not been dated. No wood is left.

Kiva A, of inferior banded masonry, dates at 1070, and it is probable that the whole cluster of kivas of similar masonry in the southeastern corner of the plaza belong to the same general period.

A great deal of building was in progress in Chetro Ketl during the period masonry III. Fig. 3, Plate 12, provides a plan of additions made during this time to the structure as we found it at the end of the period of masonry II, (Fig. 1, Plate 12). To obtain a picture of the pueblo as it appeared at the end of the period of masonry III we must superpose the building design of Fig. 3 over that of Fig. 2 and thus see the whole as a unit.

Third Period: Masonry III, IV, V. (1100-1116+). The third period of building at Chetro Ketl follows close on the second and brings to a close the main period of occupation of this pueblo. The latest date yet known for the pueblo is 1116, taken from a repair beam set into inferior masonry III, room 27, (Fig. 9, Plate 9). It is probable that logs yet uncovered will extend the building period by at least a few years.

The masonry of this period was varied. While a considerable amount of building was done, the period of originality and fine workmanship was ended. No strictly new type of masonry was devised; some of the inferior type III was still in use; types IV and V were new. Fig. 6, Plate 12, indicates the building additions made during this period; Figs. 7 and 8, Plate 12, indicate the masonry used.

In kiva G in Chetro Ketl, type V masonry is found as the final lining, covering over an older inner lining which matches the outer wall of type IV. As this kiva was superposed over the fine banded type III masonry of the large filled kiva H, the situation provides a sequence of types III, IV, and V. But in one room in the eastern back wall section of Chetro Ketl and in a kiva at Peñasco Blanco fine type III masonry is found superposed

over type V, thereby proving that the above sequence is not invariable.

Dates have been obtained on all three types, late inferior III, IV, and V.

TABLE III

DATES ON CHETRO KETL ROOMS, MASONRY: INFERIOR III, IV, V

Central and back section of Pueblo.

Room No.	Floor	M	Building date	Other logs cut for room	Repair logs	Re-used logs
22	1	4	1103			
27	2	4	1102 (3 beams)	1099, 1100	1116	1060
35	2	I3	1103			1090, 1068 1067
38	2	I3	1102			1073
Kiva G buttresses		4	1103	1097, 1098, 1099 (2), 1100 (3)		1035, 1048, 1049 (2) 1050, 1051, 1052, 1066, 1075

Kiva G was inclosed in a rectangular construction which afforded four corner sections braced by small logs extending between the walls of the circular and the rectangular structures. The mass of logs gathered together for this use evidently came from razed rooms of the period of masonry II and masonry III. Their dates ranged from 1035 to 1103; the latter is probably the building date of the structure, for adjoining rooms likewise give dates of 1102 and 1103. Undated rooms of this section—16, 17, 18, 19, 20, and 21—all of similar inferior type III and of type IV masonry, appear to belong to the same period; they have not been dated. On the eastern side of Kiva G are rooms with three sides of inferior type III masonry abutting the type IV wall of the kiva on the fourth side. The fact that beams from these rooms extend through the kiva wall buttresses scarcely leaves a doubt as to the contemporaneity of the two types of masonry in these specific cases. It would appear that the entire kiva G section, as we know it today, was constructed shortly after 1100 and that the last lining of the kiva was added, of masonry V, shortly thereafter.

The third story of the outer eastern wall of Chetro Ketl was probably raised at about this time. It is of masonry V. One beam specimen from this masonry in room 4 has been examined; it dates at 1101. Aside from this, Masonry V has been dated by superposition only.

As far as we know at present the central kiva G section is the latest large mass of construction in the pueblo. With the third floor additions of contemporary type V masonry, the general design of Chetro Ketl was completed.

Fourth Period: Masonry VI. The relative period of masonry VI, is determined only by superposition and abutment; no wood has been found in these walls. That it is later than either the fine or the inferior type III masonry is illustrated in Fig. 3, Plate 3, where in the lower left hand corner crude masonry V is seen as the final covering of the masonry III bench. This facing has been removed from the bench over the rest of the area seen in this photograph. A detail of masonry VI where it lines this bench is shown in Fig. 1, Plate 5. Superposition here is paralleled by another example in kiva F, where a square bench of masonry VI is found built over the circular bench of the inferior type III masonry of the original kiva construction. Obviously, type VI stonework was, in these cases, later than inferior type III. If some of the degenerate type III were contemporaneous with types IV and V, as indicated in the discussion of masonry types employed during the third Chetro Ketl building period, and if type VI is later than inferior type III, it therefore may be later than either of the other two and consequently the latest type in the village. The fact that it is very different and much cruder than the masonry types previously employed lends credence to the suggestion that it is the latest type. It may represent the last efforts of a few survivors after Chetro Ketl culture had ebbed and its inhabitants had mostly died or moved away, or it may even indicate the work of outside colonists who might have filtered in and taken up residence in the old pueblo. The stone work is rather similar to that of Mesa Verde, and although enough Mesa Verde pottery has not yet been found at Chetro Ketl to convince one of an immigration of people from that region, the possibility of such a movement is not deniable.

To obtain a picture of the plan of Chetro Ketl as we find it in present day excavations, we must place Fig. 3, Plate 12, over Fig. 1, and Fig. 6 over both, and thereby obtain the ground plan map shown in Plate 10.

PART II

Stratigraphic Study of the Chetro Ketl Refuse Mound

Description of East Dump. Directly east of Chetro Ketl rises the east refuse mound, one of the largest trash piles ever found in connection with southwestern pueblo sites. Located as it is in line of discharge of storm waters from one of the cañon rincons behind it, this mound has received the silt of many centuries as an accumulation covering its eastern periphery to a depth of 12 feet, 8 inches, and apparently to a greater depth on the northern and western sides. There has been no deep excavation on those sides.

This dump was examined in 1922, when trenches 11 feet wide were cut from north to south and from east to west. In 1929 a pit was sunk at the center of the dump. Neither the material from this work nor that of the earlier year was ever studied in detail. This excavation left the mound badly cut before we began trenching in 1930.

The east dump is roughly oval in shape. Although at present the surface of the dump slopes upward from the west, the old surface level as followed in the excavations was found to dip toward the east. At the center the mound was approximately 20 feet deep.

The Problem. Our objective was to discover what the dump might yield of pottery sequences, to learn whether its depth was accounted for by long accumulations of daily sweepings alone, and to find the relation of the dump strata to the periods of Chetro Ketl building.

Techniques for Investigation. Stratigraphic excavation, stratification by soil composition, charcoal dating, and the statistical treatment of potsherds taken from the excavation were the techniques employed in study of the Chetro Ketl dump.

1. *Excavation.* The dump is located directly east of the pueblo; it may be seen at the bottom of the photograph of Chetro Ketl viewed from the cliffs above, (Fig. 1, Frontispiece.) It seemed logical to suppose that people coming from the pueblo at first should have emptied their baskets of trash near the outer walls. Later they would dump on both sides of the growing mound, but as material was thrown from the peak on the farther side, eastward, the dump would grow not only vertically but also from the west eastward. As the peak of the mound would move ever farther east-

ward, a more precipitous slope would be found on that side than on the west.

With this as a premise to be tested, it was decided to sink a trench 12 feet long through the west side of the dump, to examine the center with a single pit, and to carry a trench down the eastern slope from the old central cut to where the eastern edge met the present ground level. The depth of each excavation was to be determined by the level of the original valley floor, wherever it might be encountered. The project was found to require so much time that further excavations were not attempted; intensive work carried out with requisite detail and care was obviously of more value than extensive work without detail. As time became an element before the planned excavations were completed, it was decided to carry the lower levels of excavation of the east trench to the bottom only in alternate sections, each section being 4 feet square. This allowed for plotting the strata of excavated sections from data; the intervening unexcavated sections could be plotted approximately through extension of the strata lines from excavated section to excavated section. (See Fig. 2, Plate 14, and cross section of the east mound as excavated, Plate 13.)

The four foot square sections above mentioned formed the horizontal unit adopted for the work. Vertically the material was to be taken out in 8 inch levels. From each level the material was screened, sacked, and labeled as it was removed. Later the sherds were washed, classified, counted, the percentages taken for each level, and the results tabulated and plotted for each section.

The western trench was started where a wash had eaten into the edge of the mound. For the first 16 feet east of that cut excavation was carried no lower than the stratum of sand which appears to have blown over the dump shortly after its abandonment and before the debris from the center of the mound washed down over it in a 16-inch cover. The next 12 feet, sections 5, 6, and 7, were thoroughly examined to the bottom, 16 feet below the surface. The west central pit uncovered the original valley floor at a depth of 20 feet. The east trench, 18 feet deep where it approached the center of the mound, was 13 feet deep at its eastern end, 36 feet from the center, where the dump surface meets the present ground level. Obviously the eastern side of this dump extends much farther eastward beneath the deep accumulation of sand washed over it since its abandonment.

Fig. 1, Plate 14, shows the east trench as it was being started in a series of steps, or levels. The old wide trenches which cut the dump can be seen beyond the east trench. The location of this dump in relation to the southeastern section of the pueblo is apparent.

2. *Stratification by soil content and contour.* The strata of different

materials present in this dump could be seen on the side and back walls of trenches as excavation cut downward. The contours were outlined definitely enough so that they could be traced by an observer in the trench. The sides were in even alignment and sharply cut, ready for photography, when a cloudburst one summer afternoon filled the trenches with water. The upper walls of the trench crumbled, ruining any chances for pictures, and necessitating a delay of a week for cleaning away the debris and reestablishing the measurements of depth attained just before the disaster. Measurements and drawings necessarily became the data for the final cross section chart of the dump.

The strata seen differed in soil composition and color as well as in pottery content, discovered in subsequent sherd classification. Study of the structure of the strata showed two types to be present:

(1) Strata 1 and 3, as numbered on the chart, composed of daily sweepings, showing ash, charcoal, and potsherds heaped in small overlapping mounds as thrown from the baskets of the women;

(2) Strata 2 and 4, predominantly composed of old sweepings packed in lumps, gray in color, containing some stone, ash, and charcoal, but without laminations or outlines of small piles seen in the strata of daily sweepings. This material appears to have been debris removed from some abandoned section of the pueblo cleaned out for new building or from an old dump which was moved.

In sweepings piled directly onto the dump, a stratum may be variegated in color, for the ash, charcoal, and sand are largely in pockets. The light red sand of Chaco cañon, blowing intermittently over the household debris, and to some extent mixed with that debris when prehistoric floors were cleaned, gives strata of this type a light color. When this material is first thrown out it has pockets that indicate to some extent the individual baskets-full of debris as they were deposited. If it is later moved such configuration is lost; laminations and pockets disappear, and a general mixture of ash and charcoal disseminates throughout to give the whole mass a gray color. This material was originally packed down, probably through pressure of its own weight. Dated charcoal pieces and sherd percentages confirm this identification, as will be indicated in the following discussions of stratification.

3. *Dating of Dump Charcoal.* The dating of refuse mound strata through study of the charcoal found in them has proven to be a rigorous application of Douglass' tree ring analysis. As the value of this application has been tested under the unusual and adverse conditions found in the Chetro Ketl dump, use of this technique in clarifying sequences in other southwestern dumps is anticipated.

Our first season of work on this refuse mound consisted of the west trench excavation, from which little charcoal was saved because the possibility of using such material for dating strata was yet unrealized. Later, charcoal was carefully sifted from the strata of the east trench, but before this was dated, solution of the complex problem of relative period of these strata was attempted through the techniques described above. The results of this effort led to broad hypotheses later substantiated by the charcoal dating, but until that task was accomplished no certainty in exploration of the peculiar stratification was possible. The charcoal specimens, which averaged under an inch in diameter, were pieces of branches burned in household fireplaces during the periods represented by the strata which held them. Most of them were of piñon, a wood slightly more difficult to work than pine; some were of pine and of Douglas fir and easily readable, and some were of juniper, cottonwood, and brush, and could not be used. The rings of most everaged approximately .5 mm. in width; many were microscopic. Examination was made with a 20 diameter hand glass, occasionally supplemented with a higher power lens.

As branch rings studied in modern pines are found to be somewhat more erratic than stem rings in response to weather conditions, and as most of these charcoal records were from piñon and hence more difficult than if from pine, extreme care was necessary in cross dating their charts with each other and in determining their actual dates. Fig. 2, Plate 10, illustrates the charts of a group of these piñon specimens matched and the mean of each ring, through all the specimens, taken to formulate the master chart drawn below. The master chart of this Chaco piñon was found to correspond, with but few variations, to the master chart of the yellow pine.

Of the entire dump collection, not more than 20% could be dated with confidence. The significance of even this small proportion, however, was paramount in definitely corroborating and dating the pottery sequences, in providing a key to the relationship of strata not lying in a normal chronological sequence, and in determining the relation of these strata to the Chetro Ketl building periods.

4. *Potsherds in the Refuse Mound.* Before examination of the dump could be attempted, it was necessary to establish a typological classification of pottery so that the groups could be recognized and treated statistically. The following classification was made in 1929 after several bases of distinction for representative types were tried. Difficulty lay in adequately distinguishing variations of the general Chaco black on white ware by some criteria that should be valid in marking the distinctive departure of type from type. Designs, paste composition, and paint were tried as classificatory data, but none were found to be adequate. General surface treat-

ment of polish and slip was finally adopted as the most serviceable of sub-class criteria for this situation. It was supplemented to some extent by less distinct points of departure in design, paste, and paint. The classification was used for all subsequent work, but not with a preconceived idea of the series of classes necessarily representing a chronological sequence. That they arranged themselves in a manner suggestive of a developmental order was obvious, but it was not until after an examination of the pottery distribution through the 1931 excavations of the western side of the dump that the classes were admitted to be, in general, sequential. Even here contradictions appeared in the fact that some of the apparently latest strata and latest pottery appeared low in the pile, but the variation in soil make-up of the various strata and the dating made possible by collected charcoal indicated that almost one half of this dump was of material much older than the rest and out of chronological order. Briefly put, part of the dump was upside down. The evidence and discussion of this peculiar situation will be taken up in the detailed description of each stratum.

CHETRO KETL POTTERY

Clay. Beds of white clay are found in thin strata beneath lignite layers in the sandstone walls of the cañon and under a heavy soil layer in some side arroyos. The two largest beds measure four to five feet thick. The first is found beneath a sandstone layer just outside the Gap, a break in the south wall of the cañon, (Fig. 1, Plate 2) ; the other is a thick deposit of alternating clay and thin sandstone located behind the pueblo of Hungo Pavi. This clay is fine and ranges in color from dark to light gray, speckled with occasional spots of yellow limonite and with smaller spots of dark carbonacious residue left from decaying vegetable matter. Either accidentally or intentionally a few small particles of lignite were introduced into the clay when it was damp and ready for use in molding vessels. These may be detected in some sherds with a low power magnifying glass.

The temper used was of crushed potsherds, sand, or crushed hornblend schist, which will be described later.

The white clay analyzed was taken from a stratum some three feet below the surface of the ground in an arroyo which drains into the Chaco wash about a mile below Chetro Ketl, near Yellow House. The yellow spots appearing in the clay seem to be limonite, the dark spots carbonaceous residue left from decaying vegetal matter. The composition was not distinctive; the analysis here included is of general interest only.

Analysis of Blue Clay from Chaco Cañon[17]

Silica	62.3	Magnesia	0.1
Alumina	19.0	Soda and potash	3.1
Ferric oxide	3.0	Titanium oxide	0.9
Lime	0.7	Sulphur trioxide	1.0
Combined water	10.0		

Pottery Classification. Three types of Chaco black on white ware and the typical Mesa Verde black on white ware are found in Chetro Ketl. Of the Chaco black on whites, the crudest is the coarse unpolished ware, decorated with designs such as those illustrated in Fig 1, Plate 15. The next is the semi-polished ware, decorated as in Figs. 2 and 5, Plate 15. The third is the polished ware, illustrated by designs in Fig. 6, Plate 15, and Fig. 1, Plate 16. The Mesa Verde black on white designs appear in Fig. 2, Plate 16.

Of black on red ware there is but one type, illustrated in Fig. 4, Plate 16.

Corrugated wares may be divided according to degree of fineness of paste into three types; their designs are all indented or incised on the exterior and do not vary perceptibly from type to type. (See Fig. 5, Plate 16).

I. *Coarse, unpolished black on white ware.* This coarse unpolished black on white ware is the crudest found in Chetro Ketl. Both decorated and undecorated surfaces are rough; the decorated surface was never polished, either before or after slipping, so that the white slip has a dull finish entirely free from polish.

Paste. The paste used is coarse; poor firing has left the center wall of most of the pieces dark, ranging in color from medium gray to black, with a thin edging of white at the surfaces. In all clays, even those comparatively pure, there is a small amount of carbonaceous matter that may hardly show even in an organic analysis of the clay; when the clay is fired this carbonaceous matter will volatilize and disappear if the heat to which it is subjected be sufficient. Insufficient firing will leave the center of vessel walls dark because the carbonaceous matter has not been completely volatilized and driven off.

The paste is never well mixed with the temper, the particles of which are scattered thickly but unevenly throughout. Neither are the temper particles of approximately the same size; they range from very small pieces to some three or four times the smallest in size (I, Fig. 4, Plate 14). Some very few are of fine quartz sand, but the greater amount is of crushed potsherds, unequal in size, showing light gray against the darker clay back-

17. Tests made by F. G. Hawley.

ground. In two firings these potsherds naturally have lost more of the carbon than has the clay in one poor firing.

Finish. Surfaces are rubbed over sufficiently to obliterate coil lines but never enough to produce either an even or a smooth surface. There is no polishing. Great scratches and breaks in the clay, little nodules of protruding temper, and tiny holes where the temper particles have broken out, appear most frequently on the undecorated surface but only to a lesser degree on the decorated surfaces.

Slip. A thin, paper-white slip was painted over the surface to be decorated, and, occasionally, over the exteriors of the bowls, or, sometimes, in a band extending a half inch below the rim. A very few sherds with an exterior large crude design in white lines about an inch wide have been found. Designs are placed directly over the unslipped surface. Exterior designs are rare and the sherds of insufficient size to allow one to distinguish the type of design element used.

Paint. Chemical tests indicate that the dull black paint used is composed of carbon and red iron oxide, probably the raw materials and the methods being similar to those used by Hopi today,[18] in producing black paint for pottery.

Designs. The designs of this crude ware are correspondingly crude and heavy, although there are no design elements which may be said to be typical of this type and of no other. Two main design types hold through all three classes of black on white wares in the Chaco: solid and hatched. (See Plates 15, 16. Wavered and inaccurate lines in the plates have been reproduced as they were on the sherds.)

In the solid figure designs of the unpolished black on white ware the triangle arranged in many variations and combinations is the most common. There are double rows of isosceles triangles the upper points of which touch and so leave white daimonds between each two sets of triangles, rows of triangles set upon stems, the designs sometimes set to oppose each other but more often connected to the stem lines of the uncommon interlocking scrolls, triangles in series pendant from a line encircling the interiors of bowls near the rim, and triangles set in zig-zag effect to cover the entire exterior of a vessel. The checkerboard all-over design is fairly common; each block averages about $\frac{3}{8}$ inches across. Any of these designs may be combined with sets of crudely drawn, heavy parallel lines in series about one inch across or with a band enclosed by lines somewhat heavier than those of the angled hatching with which they are filled. Crude angled cross-hatching occasionally fills the band. There is no wavy line

18. Hawley, 1929.

hatching such as is found in the semi-polished and in the polished types. Broad lined, simple geometric designs are found, but the most typical designs for this ware are variations of a triangle arrangement or a series of parallel vertical lines followed by a horizontal series.

Designs are seldom accurately or neatly drawn; uneven edges and sketchy arrangement are characteristic. The effect, nevertheless, is often pleasing. Designs run up to the rim, to a line encircling the rim, or to a line from ½ inch to 1 inch below the rim. Pitchers have a simple neck band separated from the main bowl design by a band of white. The interior surface of half-gourd dipper handles as well as the bowl of the dipper is decorated. There is more diversity in design types in this unpolished black on white ware than in those on the semi-polished black on white.

Rims. Most rims are direct, following the slope of the vessel, but some are bent outward very slightly. Many of those which were originally roughly squared have been worn rounded; some were rounded in the beginning, and a few were pinched thinner than the main wall of the vessel and rounded, (Fig. 3, Plate 15). Most of them are painted black; a few are left white, and a few are now white because the black paint has worn off. Rim tops are uneven.

Shapes. A study of potsherds can hardly give an adequate idea of all the shapes and sizes of vessels made, but we have evidence of bowls from about 4 inches in diameter by 2½ inches high to some which must have been about 12 inches in diameter by 7 inches high. Of ollas little may be said except that they existed. Canteens with small mouths were about 8 inches in diameter, and pitchers were from 4 to 8 inches high. Bowl and handle and half-gourd dippers appear to have averaged 10 inches in length; the half gourd dipper was the more common. Examples of complete Chaco black on white vessels are pictured in Pepper's report.[19]

This unpolished black on white ware with its slightly granular surface and simple crude designs shows considerable resemblance to the pottery from the pit house village of Shabik'eschee, nine miles east of Chetro Ketl. Photographs of this pottery appear in Roberts' report, 1929. The unpolished black on white ware from Chetro Ketl is superior to the pit house pottery but inferior in about equal degree to the mottled semi-polished black on white ware.

II. *Semi-polished black on white ware.* This black on white ware is distinguished by a somewhat rough surface and a mottled appearance of dull and shiny spots noticeable when one turns a piece so that the light slants down across its surface. The sherds must be cleaned and well wiped off before examination for this characteristic is attempted.

19. Pepper, 1920.

Paste. The type shows a rather fine hard paste ranging from a medium gray color to white; poor firing has left the interior of the walls of only a few pieces dark with carbon. The temper of about 2/3 quartz sand and 1/3 potsherds is evenly mixed into the paste, (II, Fig. 4, Plate 14). The size of the sand particles varies from those of the size that come from decomposed sandstone from the cliffs to particles two or three times that size. The crushed potsherds show predominantly dark against the light clay, as though the unpolished coarse black on white potsherds with dark walls had been ground to be used as temper for this second type. Potsherds of the unpolished type, when crushed, resemble closely the particles found in this semi-polished ware.

Finish. Although the interior surfaces received more careful attention than the exterior surfaces, neither is well polished; indeed, they are never even well smoothed. The size of the sand particles makes a slick finish impossible, and smoothing is never carried far enough to put the surface all on one plane; shallow hollows and bumps are characteristic. The underlying sand protrudes in small nodules; in other places the sand particles have been knocked out so that there are holes left. The undecorated surface is rough, consequently, as well as marred by scratches from careless use of the rubbing stone. Occasionally, but not often, the exteriors of bowls are roughly slipped all over, or the interior slip is carried down over the outer edge from ½ to 2 inches.

Slip. Over the surface to be decorated is laid a slip of white paint applied thinly and irregularly so that the surface shows an uneven covering. This sometimes shows crackling from drying and firing. Some attempt to polish the slip is apparent, but because of the unevenness of the surface the polishing stone struck hard on the high places and missed altogether those slightly lower. Thus, streaks from this treatment add to the general spotted finish of this type of ware.

Paint. The thick black paint is composed of carbon and red iron oxide, as is that of the unpolished ware. The paint is usually dull; in places where it has been overfired the carbon is burned out and the red-brown iron oxide appears. On some specimens the black paint is shiny, a poor glaze which appears to have been accidental and to have derived its glaze element from salt. Chemical tests show that it contains neither lead, copper, nor manganese, the glaze elements of Little Colorado wares.[20] Alkalies and salts are common enough in the area so that some might easily have been introduced into clay paint solution as extraneous matter in clay or water without the potter being cognizant of the fact that he was using

20. Tests by F. G. Hawley.

a solution differing from that he ordinarily concocted. The glaze does not resemble that of the later Rio Grande; its appearance is more similar to that of the Little Colorado, but the difference in composition bars the suggestion of diffusion. Black glaze paint is sometimes found on other types of Chaco black on white wares, but it is most common on the semi-polished.

Designs. Design elements do not differ materially from those of the other types although their treatment and execution vary between types of Chaco black on white ware, (Figs. 2, 5, Plate 15). Solid designs are still common, but the hatched are more popular. Triangles are predominant, used in simple succession, solid, or on stems, with both stems and triangles either hatched or solid. Hatching lines are finer and more accurately drawn than those characteristic of the unpolished black on white. These lines are sometimes wavered. Outlines are still heavy.

The decoration of the unpolished ware consists of designs arranged simply upon a background; the decoration of the semi-polished ware consists of designs and backgrounds so fitted into each other that the whole forms a pattern. This indicates an advance in decorative conception. Solid and hatched designs divide the surface area of a vessel quite evenly into black space and white space, or into hatched space and white space. The white and the painted areas are usually arranged as two duplicate and opposing design elements. The scroll, which becomes increasingly popular, is single rather than interlocked with a similar element in black or in hatching; it probably was seen as interlocked with the white space which opposed it and which was exactly equal to it in size and shape. This gives the effect of positive and negative designs. A few pieces show solid interlocking scrolls, their backs winged with three triangles such as are sometimes found on Kayenta black on white ware. The small necks of large globular-bodied ollas are sometimes decorated with a connected string of scrolls, sometimes with a series of encircling parallel lines, and sometimes with a series of pendant solid triangles. Designs from the bodies of pitchers are carried over the handles or under them; if under, the handle was covered with scrolls, parallel straight lines, or parallel zig-zags. Some designs are carried to the rims of vessels, but more are brought only to a line encircling the rim but about ⅛ inch below it.

Rims. Some rims are fairly flat. Others are rounded, as in the unpolished crude black on white, but the average is more even and finely finished than in that crude type, (Fig. 4, Plate 15). Some are black; some are white, as in the crude unpolished ware.

Shapes. Vessel shapes change but little, although pitchers, ollas, and bowls seem to have increased somewhat in size. The bases of a few ollas

are indented as evenly as if a small ball had been pressed up into them. Pitcher handles are of several parallel fillets of clay laid vertically, or of a broad fairly flat-surfaced band of clay, usually shaped so that the edges were higher than the center. This forms a shallow trough. Socket handles, sometimes decorated even into the interior, are found on sherds of some large ollas. Flat, projecting handles with rounding corners are also used on ollas, and pierced lug handles appear on canteens. Fragments of effigy vessels and of tall cylindrical forms are found, but little can be said of these from their sherds alone.

III. *Polished black on white ware.* The polished black on white is the best ware of this series of indigenous black on white wares. Its surface is well smoothed and even somewhat polished before the slip is applied. Some vessels show repolishing after the slip was dry; some are left slightly dull but smooth. Surface finish on this ware gives an even and pleasing finish superior to that of either of the two types already described.

Paste. The paste is hard and porous; it lies in uneven laminations with fissures scattered between. The temper of finely crushed potsherds, with sometimes a few grains of fine sand mixed in, is evenly scattered throughout the clay, (III, Fig. 4, Plate 14). As in the semi-polished black on white, the small fragments of sherds appear dark against the light gray of the clay, which is usually well fired and light and even in color.

Finish. The improved preparation of the clay and its fine texture make smoothing possible. Decorated surfaces are well rubbed down; undecorated surfaces are still uneven and slightly scratched and granulated. Those not intended for decoration are unslipped. A few pieces are slipped and decorated on both sides, and a few show a painted interior and an indented corrugated exterior.

Slip. The slip on the decorated surface is smooth and even. It may be polished or dull. It is not checked. The slip may be carried a short distance over the exterior surface of bowls, as in other black on white wares.

Paint. Dull, thick black paint of carbon and red iron oxide is used for designs, as on the other black on white types.

Designs. Just as the paste and finish of this type are better than those of the two preceding types, so are the designs more elaborate in conception and better drawn, (Fig. 6, Plate 15, Fig. 1, Plate 16). Checkerboard designs show the squares a little larger than previously. Well designed meanders are drawn with solid lines about ¼ inch wide. Interlocking rectangular scrolls with three triangle wings at each corner, stem triangle designs hatched with wavered or with straight lines, a few solid simple

scrolls, and new larger scrolls which contrast a hatched figure with one in solid black are all found. The scrolls are more common than in the other two types of black on white ware. Lines are more even in width and more accurately drawn. Some of the hatching is of evenly spaced fine hair lines that give a particularly pleasing textured surface. There are still crudely drawn designs, however, but the average is much above that of the crude unpolished ware and considerably better than the average on the semi-polished ware.

Rims. Rims receive the same treatment as those of the semi-polished ware.

Shapes. Shapes seem not to differ noticeably from those described for the semi-polished ware.

This polished black on white ware shows unmistakable advance in Chaco technique, as well as possible influence from the outside. The increase in use of scrolls and hatched designs and the advance in paste texture and surface finish are noticeable. These may have been merely a development of the Chaco technique, but the presence of Mesa Verde ware with pearly finish and frequent use of ticked rims is reflected in sherds that are obviously similar but are marked as Chaco ware by paint composition, less perfect polish, and whiter slip. Mesa Verde sherds are found in the Chaco in numbers too small (2% or less in the dump strata at Chetro Ketl) to definitely point to a Mesa Verde settlement in the cañon, but large enough to show considerable trade with the pueblos of southwestern Colorado. Some influence from that amount of trade ware would be expected. Moreover, it is possible that further work will produce evidence of immigrants entering the Chaco and making this ware.

Mesa Verde black on white ware.

The fourth type of black on white ware in the Chaco is that typical of Mesa Verde, either brought in by extensive trade, or, it must be admitted, possibly made by some small group of immigrants located in the cañon.

Paste. The paste is very fine, hard, white, and homogeneous, indicating careful mixture. Most of it has been well fired, and, consequently, is white all the way through; a small percentage is of medium gray shade due to insufficient firing. The temper is abundant and evenly mixed into the clay; it is of fine quartz sand, the particles regular in size (IV, Fig. 4, Plate 14). Occasionally a sherd tempered with crushed basalt is found.

Finish. The fine white slip is applied over a polished surface, producing a finish as smooth and almost as slick as that of a modern China plate. It is not shiny, although, after the black paint was applied, the entire surface was polished to a high even gloss. Occasionally the surface is

checked. The undecorated surface is usually thinly slipped, but, as it is only smoothed and not polished, it contrasts with the decorated surfaces.

Paint. The black paint is of carbon, probably from a vegetable extract such as that the Zunis make from the Beeweed and the Hopis from the Cleome. These modern Pueblos use the extract in solution with water containing ground red iron oxide; the ancient people of the Chaco used the same combination, but the people of Mesa Verde, of Kayenta, and of the Middle Gila used the carbonaceous solution alone.[21]

Designs. The most common design element is the interlocking scroll, the edges of which are usually plain but sometimes dotted, (Fig. 2, Plate 16). Opposing triangles edged with dots are found. Bands of parallel lines are used, but hatching is not seen. Many designs are carried out in solid lines slightly less than ¼ inch across. Some are carried over the entire interior surface; some merely encircled the interior rim. Decoration extends to the rim or to within ⅛ inch or less from it.

Rims. Rims are usually square. Some times the edges are even slightly higher than the center. Some are left white; some are ticked with black dots. None are painted black.

Shapes. The sherds observed were all parts of bowls or of half gourd dippers. If ollas were made they were rare.

Black on red ware. The source and position of the black on red ware found in the Chaco is difficult to determine. It closely resembles the black on red ware from Kayenta. If it was made in the Chaco, where the requisite red clay is present, it was never popular enough to have existed in quantities. If it was brought in from Kayenta or from south of Mesa Verde, it must have been important as a trade item.

Paste. The clay of the paste contained a small amount of iron which burned to a light buff or orange color, although some pieces appear gray from poor firing. The temper is of finely ground white or orange potsherds and of fine quartz sand. Temper is not abundant and was evenly mixed into the clay, (VI, Fig. 4, Plate 14). In clay and temper the resemblance to Kayenta black on red is thus seen to be as striking as in surface finish.

Finish. The sherds show an excellent finish, better than that of any of the known Chaco black on white wares and comparable with the work of Mesa Verde or of Kayenta potters. Bowls are polished on both sides before slip is applied inside and out, except in the case of seed jars. The slip is polished. Designs drawn over it are in dull black paint containing carbon and either red iron oxide or manganese, such as is found on the Kayenta

21. Hawley, 1929.

black on red ware. On the exteriors of a few vessels, red slipped indented corrugations are employed as decoration which contrasts with the painted interiors.

Paint. The thin slip is made from a ferruginous orange clay, the iron of which burns to red iron oxide when fired. One sherd was found in which the red slip covers the exterior and extends only 1½ inches below the interior rim. Below that the light orange paste is left uncovered but polished, and the black designs are applied directly.

Designs. Solid, heavy line designs, the lines being about ¼ inch across, are contrasted with duplicate designs in plain or wavered hatching, outlined with lines of the same width as the hachure lines, (Fig. 4, Plate 16). The hatched bands are ½ inch across. Some of the work is accurately drawn. The average is good. Checkerboards and triangles are popular; the hatched running designs are very common.

Rims. As in the black on white wares, rims vary between the direct flat type and the direct slightly rounded type. Rarely one flares outward. They are left red.

Shapes. Potsherds found indicate that bowls averaging 12 inches in diameter and 5 or 6 inches deep were the most common forms of the black on red ware. There are parts of bowl and handle dippers and of small seed jars 7 or 8 inches in diameter, and 6 inches high.

In the Little Colorado area, on the north Middle Gila, and on the Upper Gila bowls are common in the black on red ware, but ollas are rare. There are neither seed jars nor dippers. Moreover, the paste, surface finish, and paint of these more southern black on red wares do not as closely resemble this found in the Chaco as does the Kayenta black on red. In the Kayenta area small seed jars are common and dippers are found. Thus, it is apparent that in paste, temper, paint, design, and shapes the black on red ware of the Chaco resembles the Kayenta black on red more closely than it does any other ware. As a conclusion based on present evidence, we can say that it appears to be Kayenta ware brought in by extensive trade, but the possibility that we may eventually find it was made in the Chaco must not be overlooked.

Kayenta Polychrome ware. In connection with evidence that the black on red ware was brought in by trade, we note that a few sherds of typical Kayenta polychrome ware are found in the Chaco and prove that trade with this district was carried on.

Plain red ware with burnished black interior. This ware has the finest surface finish of any found in the Chaco, but like the black on red, it ap-

pears to be a trade ware rather than indigenous. It is common in the Flagstaff district, in the Little Colorado, and in the Middle Gila. Proximity suggests that it was traded into the Chaco from the Flagstaff or Little Colorado districts rather than from farther south.

Paste. The paste closely resembles that used in the black on red ware; the temper is likewise similar, (V, Fig. 4, Plate 14). The smudging of the interior darkens the clay about half way through the wall.

Finish. This ware is well smoothed before the red slip is applied and excellently polished afterwards so that both interiors and exteriors are glossy. The highest gloss is on the interior. After polishing, these interiors are filled with smoldering organic matter and allowed to stand until the soot has so deposited itself in all the pores and interstices of the clay that the black is permanent.[22]

A few sherds show indented corrugated exteriors slipped with red and polished enough to give the raised nodules a gloss.

Rims. Both rounded and squared rims are found, the squared being the more common.

Shapes. All the sherds of this type have come from bowls about 10 inches in diameter and 5 to 6 inches deep.

Corrugated Wares.

Although the Chaco corrugated vessels were probably used for cooking, almost all of the sherds being blackened by fire and many caked with thick soot, a large proportion are decorated. Incisions, indentations, and combinations of plain and indented coils form simple geometric designs. Many vessels are decorated with indentations entirely covering the corrugated surface; some are corrugated but not indented.

Paste. The paste of the corrugated ware may be divided into three general classes:

(1) Ware with poorly mixed friable paste, tempered with coarse sand.

(2) Paste showing a high percentage of temper of finer and more evenly sized particles of sand.

(3) Fairly fine and hard paste containing fine sand or crushed basaltic temper, and, occasionally, crushed potsherds. As the exterior surface on all three types is similar, the finish can not be used as basis for division into sub-classes. As a matter of fact, it is possible that the classification by paste is artificial, for although it appears that the classes should arrange themselves in some chronological sequence in the Chetro Ketl refuse mound, such is not the case.

22. Hawley, 1929.

Interior surfaces vary more than exterior surfaces. Pieces with coarse temper show large sand particles protruding through the surface. Those of the next finer temper show a surface only moderately granular. The interior surface of the ware with fine temper sometimes has almost the appearance of being slipped.

The clay used is gray-white and varies in darkness of shade according to the firing received, much as the clor varies in the clay of the black on white types. The corrugated ware with the coarest temper is often, but not always, very dark; that with the finest temper is occasionally, but not always, a clear white.

Basaltic temper. The corrugated ware tempered with dark glittering crystalline particles is found in twice the amount of that tempered with sand. Microscopic examination of thin sections of this pottery show the temper to consist of angular pieces of several kinds of broken minerals. The most common are of a very dark green color and have the appearance of pyroxine or hornblende; there were also a number of pieces of greenish-yellow mineral that appear to be olivene and some that are apparently feldspar. A very few pieces of quartz appear. These minerals would indicate that the temper was made by grinding up some dark colored volcanic rock, as hornblende pyroxene or a similar basaltic material. A very few pieces of worked stone of this type have been found in the Chaco area; when crushed the particles are identifiable with those of the basaltic temper. The great amount of pottery tempered with this material is puzzling, however, for no volcanic deposits are known to exist within 60 miles. Importation of stone for temper of a great part of the corrugated ware, when the rest is tempered with sand or with crushed potsherds, is unexplained.

Finish. The three types of corrugated ware vary but little in decoration; coils range from four to ten to the inch. The finger of the potter was drawn across the damp surface of some of the pieces when they were being made. Vertical or slanted parallel lines are indented to form simple band patterns or triangles surrounded with a background of plain ridged coils, (Fig. 5, Plate 16). This decoration is used on all three types of corrugated but in the second type some pieces are also sharply incised with narrow vertical lines in combinations of different lengths. In the third type incised lines, vertical or slanted, are arranged to produce designs that are more ornate. In no case, however, are these designs mutually exclusive, type from type.

Of designs used, the ever-varied triangle seems to be the most common. Triangles are indented while the background is left only ridged. Concentric V's are made in the same way. A few pieces are left plainly ridged except

for cross lines drawn with a sharp instrument while the clay is soft. Of this technique, parallel line designs and triangles of lines of graduated lengths are seen. Small coiled fillets of clay ¾ inch in diameter are often found placed on the two opposite sides of the rim of ollas, as is common on rims of corrugated ollas from Kayenta.

Rims. Rims are pinched slightly and curved outward; the edge is roughly rounded. The entire rim is made to look like one wide fillet of clay, from ½ to 1¼ inches broad, added above the last coil and lapping over it.

Shapes. Large, wide-mouthed ollas and smaller pitchers are characteristic shapes for all three types of corrugated ware. Handles vary in shape. In the coarse ware, small cone-like handles are applied about 2 inches below the edge of the vessel. A few handles are somewhat thicker and wider and curve downward at the end. On the second coarsest ware some handles are hollow knobs about ¾ inch across. The finest corrugated ware shows as the most common handle a larger heavy cylindrical knob bent downward but not quite meeting the wall of the vessel. The handles described on the other two types of corrugated ware are also found on this last type, although not as frequently.

STATISTICAL SIGNIFICANCE OF POTSHERD DATA

The potsherds screened from the east dump of Chetro Ketl were washed, classified, and counted, the results tabulated, and averages made for each stratum. Computations on west trench material show that the number of sherds per unit of soil removed is fairly constant from top to bottom of the dump, regardless of type of stratum, except for the expected dimunition in the lowest levels. The condensed results are given in table IV; this material may be examined in more detail in protocol 2 at the conclusion of this paper.

Percentages of each type per section-level are set out as a columnar graph for the west trench, (Figs. 1, 2, Plate 18), but as the results are found to appear as clearly in the graphs of averages per stratum, only the latter were made for data from the east trench, (Fig. 1, Plate 17). Averages were figured out only on the total number of all sherds per stratum as 100%, but also on the total number of black on white sherds per stratum as 100%. This manipulation allowed determination of relative period fluctuation in the three types of Chaco black on white ware previously described, a matter of chronological importance. A similar graph for the corrugated cooking ware, which runs about 50% in every stratum, indicates no consistent variation, type by type. Hence corrugated ware is not considered further in the following statistical study.

TABLE IV
SHERD OCCURRENCE PER LEVEL—WEST TRENCH, EAST DUMP

Section	Stratum	No. Levels	No. Sherds	Mean No. per Level
Sec. 7	4	12	1524	127
	3	3	391	130
	2	6	777	129
	1	3	199	66
Sec. 6	4	9	1069	119
	3	5	687	137
	2	4	542	136
	1	2	113	56
Sec. 5	4	9	1090	121
	3	4	581	145
	2	3	343	114
	1	2	108	54

The significance of the differences between the averages for each type in each stratum was mathematically tested by Mrs. Dewey through application of the "Significance tests," as given by Yule.[23] This test is designed to indicate, as far as is mathematically possible, whether the variation seen between the different percentages of two variables in two situations is significant and hence indicates actual variations between the two aggregates, or whether the variations may be explained by chance alone. The formula depends on application of the fact that if two variables are quite independent, so that the coefficient of correlation between them is zero, the standard deviations of their sum and of their difference have the same value. Tests of this type are valid only when applied to random samples collected by some technique free from bias. Collection of sherds level by level in the trenching of a dump satisfies this requirement.

Significance tests.[24]

First: Let us consider that a given difference is not significant, and that the two samples from which this difference arises come from the same aggregate. In the two samples taken from this aggregate, we discover proportions p_1 and p_2 of a variable, x. The size of the samples are n_1 and n_2 respectively. If both samples are drawn from the same aggregate, their true difference is zero. We now ask the question: Can the difference observed between the two proportions have arisen merely as a fluctuation of sampling? Since the actual proportions of the x's in the aggregate is not known, the closest approximation we can figure for it is given by the formulae:

23. Yule, 1929.
24. Mrs. G. Dewey, Tree Ring Laboratory, University of Arizona.

$$p_0 = \frac{n_1 p_1 \quad n_2 p_2}{n_1 \quad n_2} \qquad ; \qquad q_0 = 1 - p_0$$

The standard deviations of the two samples would be given by the formulae:

$$\sigma_1 = \sqrt{\frac{p_0 q_0}{n_1}} \quad , \qquad \epsilon^2_{1,2} = p_0 q_0 \left(1/n_1 + 1/n_2\right)$$

$$\sigma_2 = \sqrt{\frac{p_0 q_0}{n_2}} \quad . \qquad \text{Then:} \quad \epsilon_{1,2} = \sqrt{p_0 q_0 \left(1/n_1 + 1/n_2\right)}$$

The following notation explains the symbols used above:

p_0 = true proportion of x's
q_0 = true proportion of non-x's
p_1 = Observed proportion of x's in the first sample
q_1 = Observed proportion of non-x's in the first sample
p_2 = Observed proportion of x's in second sample
q_2 = Observed proportion of non-x's in second sample
n_1 = size of first sample
n_2 = size of second sample
σ_1 = standard deviation of first sample
σ_2 = standard deviation of second sample
$\epsilon_{1,2}$ = standard deviation of difference between the two proportions

Then, if the observed difference be less than three times the standard deviation of the difference, that observed difference may have arisen as a fluctuation of sampling. But if the observed difference is greater than three times the standard deviation, the two samples must come from different aggregates. The basis for this assumption lies in the fact that the chances of accidentally obtaining a deviation greater than three times the standard deviation are only 27 in 10,000.

In this paper the test was applied to each of the six types of pottery. The tests were made in two divisions. The first set of tests is on the material from the west trench, the second on material from the east trench. The

difference between the percentages of a given type were tested between each stratum, the number of those sherds from one stratum being taken as the first sample, the number found in another as the second. As an example, let us take polished black on white as our variable x. Since there are six possible combinations of the four strata in which polished black on white occur in the west trench, six tests of the difference in proportion are necessary. Suppose we are testing the difference between strata 1 and 2. Then n_1 is the number of sherds occurring in stratum 1; n_2 the number in stratum 2. In each case the values of n_1, n_2, p_1, p_2 are taken from the sherd data, (Protocol 3 and Figs. 1, 2, Plate 17). The formulae used are those given above; the resulting data of the significance tests appears in the following table, V, in which significance is indicated by the word *Yes* placed opposite the pair of strata tested.

TABLE V
SUMMARY TABLE OF RESULTS

Table of results of the difference between proportions of a type of ware in two compared strata is significant as shown by the test, that fact is here indicated by the word "yes" placed opposite the pair of strata tested.

	Black-on-White		*Corrugated*	
Stratum	East trench	West trench	East trench	West trench
	Polished		*Fine*	
1 & 2		Yes		Yes
1 & 3		Yes		No
1 & 4		Yes		No
2 & 3	Yes	Yes	Yes	Yes
2 & 4	Yes	Yes	Yes	Yes
3 & 4	Yes	Yes	Yes	Yes
	Semi-Polished		*Medium*	
1 & 2		No		No
1 & 3		No		No
1 & 4		Yes		No
2 & 3	Yes	Yes	No	Yes
2 & 4	No	No	No	Yes
3 & 4	Yes	Yes	No	Yes
	Unpolished		*Coarse*	
1 & 2		No		Yes
1 & 3		No		Yes
1 & 4		No		Yes
2 & 3	No	Yes	No	No
2 & 4	Yes	No	No	No
3 & 4	No	Yes	No	No

Conclusions on Significance Tests. For the sake of brevity, in this discussion two strata are spoken of as being the same or different with respect to a certain type of pottery when it is meant that the two strata represent the same or different aggregates in regard to pottery type.

Strata 1 and 3. Since stratum 1 is not found in the east trench, comparisons are limited to the material of the west trench. Six comparisons are made, three on the Chaco black on white types, three on the corrugated.

Five comparisons show the differences to be not significant. The only difference which tests to be significant is that in proportions of polished black on white pottery, which is found to occur in actually different proportions to the total of sherds in all strata.

Strata 2 and 4. In both the east and the west trenches strata 2 and 4 are found to be significally different in proportions of polished black or white ware, and of fine corrugated ware. They are not significantly different in content of semi-polished black on white nor of medium corrugated ware. In the east trench the strata show a situation slightly different in the former but not in that the proportions of unpolished black on white are different in the former but not in the latter. Similarly, there is significant difference in medium corrugated ware in the west trench but not in the east. Such variations between the contents of these two strata as tested on different sides of the dump are probably to be explained as minor changes becoming evident in the east-west expansion of the dump.

Other pairs of strata. In both trenches strata 3 and 4 are found to be different in comparisons of polished black on white, semi-polished black on white and fine and coarse corrugated wares. In the west trench but not in the east the difference between proportions of unpolished black on white and of fine corrugated wares are significant. Strata 1 and 2 are significantly different in polished black on white, in semi-polished black on white, and in coarse corrugated wares.

Strata 2 and 3 are significantly different in polished and in semi-polished black on white and in fine corrugated wares. In the west trench these strata show significant variations between unpolished black on white and between medium corrugated wares.

In view of these results it is reasonable to say that, with respect to most of the pottery types, strata 1 and 3 are essentially the same. Strata 2 and 4, although not the same, are similar to each other and contrast with strata 1 and 3. Soil composition and dates on the strata must be considered before further conclusions can be drawn.

DETAILED DESCRIPTION OF STRATA IN THE EAST DUMP

Four strata are encountered in trenching through the refuse mound. They are numbered from the bottom upward, number 1 being the stratum first laid down and number 4 the last.

Stratum 1. Directly above the undisturbed sand of the original valley floor, as uncovered in the west trench, lies a thin layer rich in charcoal. The upper part of this stratum is lighter in color and more sandy than the bottom, a difference that is indicated by the line drawn through this stratum on the

chart, Plate 13. Small mounds and pockets of ash, sand, and charcoal identify the formation with that seen today in the accumulating dumps of the modern pueblos. Basketful by basketful the trash was thrown out, marking the pockets and lenses of charcoal and ash we find in excavation, first near the outer wall of the village and then farther eastward. The peak of the mound grew progressively eastward. As diagrammed in the chart, the highest point of the first stratum located in the west branch was at the west side of section 5; its peak probably lay somewhere between there and the western edge of the mound. The stratum remained almost horizontal through section 6 and dipped downward through section 7, showing that the valley floor evidently sloped eastward here. Stratum 1 runs out somewhere between section 7 and the west-central pit. There is no trace of it in the east trench.

That accumulations grew up around the spreading base of the mound is probable, but while we are dealing with material uncovered by a trench near the center of the dump, the problem of peripheral chronologies need not be considered.

Of the charcoal saved from stratum 1, not a piece was datable; ring sequences were too short or too erratic. As will be indicated in the discussion of stratum 3, which is dated, strata 1 and 3 are so similar in pottery distribution and soil composition as to appear of closely sequential periods. Stratum 1 was obviously the first to be laid down, at least in the section of the dump examined. Approximate dates for this stratum will be given subsequently.

As previously stated, distribution of corrugated ware throughout the different strata shows no consistent variation; graphs of their relative percentages may be seen in Figs. 1 and 2, Plate 17. The discussion of potsherd content of the strata will be based on percentages of the three types of black on white wares as described in the section on *Pottery Classification.*

Black on white sherds from stratum 1 occur in the following percentages, (based on total sherds as 100%):

Polished black on white	33.2%
Semi-polished black on white	22.2%
Unpolished black on white	9.5%

The percentages, level by level in each section of the west trench, are shown graphically in Fig. 1, Plate 18. The columns represent the actual percentages of black on white wares. Combined into data representing each stratum through the set of sections in both east and west trenches, Fig. 1, Plate 17, shows the averaged figures of each type reduced to histographic form. Fig. 2, Plate 17, indicates the relative proportions of each

black on white type in each stratum as these ratios would be if we disregarded all other pottery types and took the total of the three classes of black on white in one stratum as 100%. We have in these ratios the proportion of each type of black on white ware to the other black on white wares of a stratum, and hence a comparison of relative percentages of each in the various strata.

Stratum 2. The second stratum illustrated in the cross section of the dump, (Plate 13), is slightly thicker than the first. It shows its peak in section 5, slopes rather precipitously downward in section 6, straightens somewhat in section 7, and appears in a thin layer as the lowest deposit almost 20 feet beneath the top of the dump in the west-central pit. Throughout the east trench its depth remains fairly constant, but the uneven surface of the ground on which it was deposited appears in the varying levels of its base line.

Stratum 2 consists of a mass of refuse that comes out as packed clods of debris. Its gray color appears to be the result of general mixing of ash and charcoal throughout. The marked difference in structure between this layer and the mounded and pocketed layer of daily sweepings beneath it led to comparison of the former with other material taken from the pueblo. In appearance the material of stratum 2 is found to be very similar to that removed in digging through the debris of the Great Sanctuary. Except for the fact that it is filled with clods and stone, the material of stratum 2 is similar to that of stratum 1 and 3 after that material is removed and mixed in the discard pile.

This material of stratum 2 could have been thrown onto the dump in its mixed state if it came from old refuse areas in the pueblo cleared of accumulations to permit the erection of new rooms or kivas. Old abandoned rooms and kivas are frequently filled with debris in modern pueblos. If any of these were to be cleaned out for re-use, or if old dumps were to be moved from one location to another, the mass of material after being deposited the second time would show few or no laminations. The whole would be comparatively homogeneous.

When found on a new dump, such material would be mixed with appreciable amounts of pottery in use at the time of the second deposition, for the daily household sweepings would be cast onto the growing pile week by week. These small contributions to the growing stratum would accumulate more slowly than the older twice moved material cleared from elsewhere and re-deposited as quickly as the builders could transport it in their baskets.

The black on white potsherd percentages for this stratum are:

Semi-polished black on white ---------- 26.5%

Polished black on white	14.0%
Unpolished black on white	9.5%

It is noticeable that while polished black on white ware was predominant in stratum 1, of daily sweepings, the semi-polished is predominant in stratum 2, composed mainly of old debris.

Only one charcoal specimen from stratum 2 is dated. It was cut about 1090 A. D., (1060+ca. 30 rings estimated to have been burned off the exterior.) This specimen gives the approximate date when the top of stratum 2 was being deposited; it is not the date of the material predominantly composing the stratum. Evidence for this statement comes from study of strata 3 and 4 and will be taken up subsequently.

Representative dates on the dump strata are marked on the cross section chart, (Plate 13), according to the levels from which they were taken; the complete set of dates for all material dated in the dump is compiled in Protocol 2.

Stratum 3. The third stratum is a thick layer of ash, charcoal, sand, and other debris. Although it makes up less than half the total thickness of deposit in the area cut by the west trench, it composes almost the entire central section of the dump, as cut by the west-central pit, and two thirds of the eastern section. It is chiefly an accumulation of daily sweepings, into which was mixed a small amount of the old debris which largely composed strata 2 and 4. The peak of stratum 3 is seen at the present surface of the mound in the west-central pit and at the upper western edge of section 9 in the east trench.

Polished black on white ware is predominant in stratum 3 just as in stratum 1, also of daily sweepings. The proportions of black on white ware in stratum 3 run as follows:

Polished black on white	27.3%
Semi-polished black on white	16.9%
Unpolished black on white	5.5%

A large collection of charcoal was taken from stratum 3, and more specimens are dated than from any other one stratum; see Protocol 2. As usual, the difficulty of estimating the number of rings burned off the exterior of specimens is present. Two groups of dates are found, one in the late 900's, one in the 1000's and early 1100's. Let us first consider this latter group.

In Protocol 2 the underlined figures are the latest obtained for each level, that is, the dates on pieces having the fewest rings burned from the exterior. Nevertheless corrections for the missing exterior rings must

be made in each case. The estimated date thus obtained is given in parenthesis.

The date found nearest the bottom of this mound is 1084+ca. 6, or 1090. It comes from level 18, section 5, at the bottom of stratum 3 in the west trench. The date of 1067+ca. 20 is found at level 26, west-central pit, two feet above the bottom of stratum 3, and 1060+ca. 30 at level 27, section 5, marking the top of stratum 2 and the bottom of stratum 3 in the east trench. 1090 is taken as a fairly close approximation of the actual date which marks the top of stratum 2 and the bottom of stratum 3.

The latest date on stratum 3 is 1106+ca. 4, or 1110 approximately. This comes from level 15, section 8. From level 17, section 4 comes the date of 1105+ca. 5, or approximately 1110. When allowance is made for the slope of the stratum, these dates are seen to come from a horizontal plane slightly above the center of stratum 3 and roughly parallel with the top of the dump. The rate of deposition of this stratum and the computed dates of its upper levels will be discussed later.

The other group of stratum 3 dates, clustering around the middle 900's, is represented by seven scattered pieces of charcoal whose dates group with those of stratum 4. Stratum 4, as will be seen in its detailed description, is composed of a gray unmarked mass of material in general similar to that of stratum 2, containing a preponderance of semi-polished black on white ware dating in the late 900's. That some dates in the 10th century should come from small masses of the same material observed scattered through the mound-marked main contents of stratum 3 is not a matter of coincidence. Apparently a small amount of old debris was being moved during the period of deposition of this stratum. To judge by the position of the early dated specimens in relation to the depth of the stratum, this process of clearing was being started during the latter part of the period of stratum 3 and developed into a major operation at Chetro Ketl during the period of stratum 4.

Stratum 4. Stratum 4, the uppermost on the dump, is of the same unstratified packed debris as stratum 2 and shows a similar general potsherd distribution. It represents a period of clearing away the old debris originally deposited elsewhere in the pueblo.

On the west side of the dump the stratum is divided horizontally by a layer of sand. It seems evident that the top of the lower strip of this debris was the surface of the dump at the time that it was abandoned, and that for some time sand blew over it until a layer averaging 16 inches thick accumulated. The few sherds which drifted into it were probably washed down from the peak of the dump. Unless caught by bushes, sand rarely accumulates on the peak of a mound; we find none on this. The prevalence of

westerly winds in the cañon would explain the presence of sand on the west slope but not on the east.

Above the sand is another layer of debris, identical in type to that below the sand. It would appear that after the sand had accumulated on these slopes, the peak began to weather and erode, washing farther and farther down the sides of the dump, until finally a layer about as thick as the sand had accumulated. If this washed material came from the peak of stratum 4 at the top of the dump, the sherd percentages in it might be expected to compare with those of the rest of that stratum, which would be the lower strip of stratum 4 debris in sections 5, 6, and 7, west trench. The relative distribution found in the potsherd count is seen to be identical in both the upper and the lower levels of the stratum.

The peak of the dump today shows no remains of stratum 4, which we presume once existed there as on the slopes where it is still found. If the material of the upper layer of stratum 4 on the west slope weathered off the peak of the dump, it is reasonable to suppose that stratum 3 might be left uncovered at the top of the mound. Eight hundred years of the brief but torrential summer rains and heavy winter snows characteristic of the Chaco might easily move between one and two feet of soft material from the peak of a mound protected by no ground cover.

The potsherd distribution of stratum 4 shows the following percentages:

Semi-polished black on white	33.5%
Polished black on white	16.2%
Unpolished black on white	9.9%

The dates on charcoal from stratum 4, with one exception, all lie in the middle 900's; see Protocol 2. An average of 10 to 20 years must be added to each to account for the rings burned from the exteriors: (see "Collection and Preparation of specimens" for explanation of technique). That these specimens are not merely centers of branches from whose exterior a large number of rings has been burned is finally proved by the fact that the present exteriors of these are as early in date as the interiors of most of the charcoal from other strata. As ring size indicates, both groups come from small burned branches, and as both groups average the same in diameter and in ring width, it is obvious that the group with exterior dates in the 900's is not one with the group giving interior dates in that period. These early dates represent the old removed debris itself. Referring to the dates of the building periods, we see that these dates of stratum 4 material come into the little known period of masonry I, (945-1035). The material composing stratum 4 would appear, then, to have been deposited originally at some other spot during the period of masonry

I, and the potsherd distribution of the stratum should then represent, in general, that of the period of masonry I.

The material was later re-deposited on the east dump as the fourth stratum. The one date in this stratum falling after the year 1000 is 1054. From the exterior of this specimen approximately 50-70 rings are burned away. Adding an average of 60 years to this last ring present gives an approximate date of 1124 for level 9, section 5, from which the specimen was taken. It was found directly above the remains of the only interment in the mound. Its presence may have been intrusive if the burial was intrusive; otherwise, it must have been deposited in daily sweepings thrown out at the time the older material was being transported. In either case, it evidently represents the period shortly before or after the dump was abandoned and before the abandonment of the pueblo, for the burial accompanied by Chetro Ketl pottery was without doubt that of a resident of the pueblo.

That stratum 4 was laid down after stratum 3 is self-evident. Whether or not this one piece of charcoal came to its position in the stratum by accident or by deposition can not be decided with certainty. We do know, however, that if the upper levels of stratum 3 were post-1110 A. D., the material of stratum 4 must have been laid down between that time and the time of abandonment of the pueblo.

RATE OF REFUSE ACCUMULATION

Unfortunately we do not have dates from all the strata of the east dump, but if we consider all the other data that may bear on the relationship and relative dating of these strata, an approximate chronology can be constructed. Our approximation to a final date on the top of the dump can be checked against the latest dates known on Chetro Ketl and on other Chaco ruins. If we can figure the rate of accumulation of daily sweepings in stratum 3, which is best dated, and then discover the proportionate amount of similar daily sweepings mixed into the other strata which are preponderantly of old debris, we can compute approximate dates for the latter.

First let us consider the actual dates with which we may deal. The bottom of stratum 3 and the top of stratum 2 have been given the approximate date of 1090; (see p. 87). The east trench gives the best series of dates for this stratum: from level 17, section 4 comes the date of 1105+ca. 5, and from level 15, section 8 comes the similar date of 1106+ca. 5, both dates being rounded off as 1110. If we consider 1090 as the date of the top of level 27, or bottom of level 26, section 5, and 1110 the date of level 16, sec-

tion 5, (following the slope of the stratum between sections 4 and 8 where levels 17 and 15, respectively, date 1110), we have 10 levels representing an accumulation period of 20 years. The rate of accumulation is seen to be about 2 years per level.

That the center of a dump would grow faster than the sides is apparent; peaked mounds in themselves evidence the tendency to dump on a center. The rate of deposition of 2 years per level is figured for the east slope of the Chetro Ketl dump. This area is chosen both because of the maximum number of dates present and for consideration, and because stratum 4 is here still present and unmodified by the sand layer and the mass of eroded material found on the west slope. Except for figures on stratum 1, we will continue our estimates of the age of the dump through data from the east slope, but the dates on upper and lower borders of strata and the final date of beginning and end of deposition on this dump pertain to the entire cross section investigated.

Level 20, section 5, dates 1090+ca. 10, or 1100. As this level is six levels above that dated 1090, the rate of deposition would indicate it should date about 1102. The actual date plus an estimation of burned-off rings is seen to check closely with the calculated date.

Level 15, section 8, five levels higher, gives the date of approximately 1110, as cited above. Level 11, section 4, dating 1099+ca. 20, or 1119, is at the top of stratum 3, four levels above the date of 1110 and by rate of deposition would calculate to date 1118. The two figures again are seen to closely approximate each other and consequently to check the estimated local rate of deposition.

RELATIVE DATING OF STRATA 1, 2, AND 4

Referring to the significance tests, Table V, we see that strata 1 and 3 are essentially alike except for proportions of polished black on white ware. About 6% more polished ware was made during the period of stratum 3 than in the period of stratum 1. As stratum 3 was obviously later than stratum 1, it is to be expected that more fine ware might have been made during the later period.

The contents of stratum 2, preponderantly of old debris but partly of daily sweepings, as previously described, would contain some daily sweepings presumably approximating the composition of stratum 1, which shortly preceded it. The small amount of sweepings in stratum 4 would, similarly, resemble those of stratum 3. That a marked change would have taken place between the daily sweepings in each of these pairs is improbable when we consider that strata 2 and 4 were preponderantly of old debris

and consequently would have been laid down during brief periods of time.

If strata 1 and 3 are both of daily sweepings and essentially alike, their rate of deposition can be thought of as essentially the same, providing the pueblo population remained of the same relative size in proportion to the surface of the dump in use. That the pueblo size did not increase unduly during the long period of stratum 3 deposition appears in the map of pueblo additions between the years 1100 and 1116, (Fig. 6, Plate 12). Strata 2 and 4, statistically indicated to be essentially different in content of polished black on white, although both are preponderantly composed of old debris high in semi-polished black on white ware, may owe that difference entirely to admixtures of different proportions of the types of sweepings of strata 1 and 3 respectively.

If strata 2 and 4 are known to contain some part of the sweepings typical of stratum 1 and 3 respectively, then the rate of deposition of strata 2 and 4 should be proportional to the rate of deposition found for stratum 3 in ratio to the amount of sweepings present. This proposition is dependent of course, on the proviso that pueblo population did not greatly increase in that time and that any other possible disturbing factors, of which we have no evidence, may be considered negligible. The rate to be figured is thus seen to be only roughly accurate.

In figuring the periods covered by the deposition of each stratum, let us work from the top of the dump downward, using the columnar chart of pottery percentages found in each stratum, (Fig. 1, Plate 17), as data. Considering the limitations of our technique, there is no advantage in using more detailed figures than the rounded percentages which may be read from the columns.

Stratum 4. If polished black on white ware is taken as 100% in stratum 3, which is composed almost entirely of daily sweepings, semi-polished black on white figures to be 64% and unpolished black on white as 20%. We know stratum 4 to be preponderently of old debris with some admixture of daily sweepings. Let us measure the variation between contents of stratum 3, which is of sweepings, and stratum 4, which is mixed. In the latter, polished black on white ware is represented by a 3½ cm. column. If this be taken as a unit, 100%, and if we had 64% semi-polished black on white, as in stratum 3, the column representing the semi-polished ware theoretically would rise only 2.1 cm. in height. Actually it measures 6.8 cm., which is 4.7 cm. or 223% excess. Of the unpolished ware we find, similarly, 1.35 cm. or 208% excess beyond the theoretical .65 cm. expected. This situation points to the presence of daily sweepings in stratum 4. The two figures may be averaged as about 215%.

If the average of 5 levels for stratum 4 would have required 10 years for deposition providing the material had all been sweepings, then in its actual composition of 100/315 daily sweepings, the stratum would take 100/315 × 10, or 3.2 years of accumulation. As stratum 3 was figured to have been completed about 1119, we estimate the top of stratum 4 to have been laid down about 1122. As admitted previously, we lack dates on the latest period and on the time of desertion of Chetro Ketl, but this date of 1122 may be compared with 1127, the latest on Bonito, and 1123 and '24, the latest dates on Yellow House and Kinbiniola, respectively.

Stratum 2. If we take the amount of polished black on white ware present in stratum I as 100%, we find 45% semi-polished and 20% polished ware. Using these percentages as the yardstick for comparing the amounts of each in stratum 2, we find there a 3 cm. column of polished black on white representing the 100%,* an excess of about 4 cm. or 290% semi-polished ware beyond the 1.35 cm. to be expected in sweepings according to the proportions of stratum I, and an excess of 1.5 cm. or 250% beyond the .6 cm. to be expected of unpolished ware. These figures indicate between 250 and 290% (averaged as 270%) more old debris than daily sweepings in stratum 2.

From the data at hand, it can be seen that of the three levels of stratum 2, 100/370 will be daily sweepings. If it were all daily sweepings, the accumulation period would be 6 years; with 100/370 sweepings, only 1.6 years would be required for deposition.

If the top of stratum 2 in section 5 at the center of the east trench be dated at 1090, then the bottom would date about 1088. As nothing is found beneath stratum 2 on the east side of the dump, this would be the date when deposition was first begun here.

Stratum 1. Beneath stratum 2 in the West trench is stratum I, two levels thick. At the daily sweeping accumulation rate of 2 years per level, this would take 4 years for accumulation, making the bottom of the layer date about 1084. This would be the date of original deposition on the west side of the dump.

Summary of East Dump Strata, Composition and Dates.

Reviewing our strata dates from top to bottom of the east dump, we find, first, stratum 4, composed almost entirely of twice-moved debris, dat-

*The use of polished black on white ware as the standard unit for comparison in both types of strata would be entirely valid only if no polished black on white ware had been made during the early period represented by the old debris. We do not know this to have been the case. But the fact that the polished ware runs low in stratum 4, which is seen to contain lenses of daily sweepings mixed with the twice moved material, dating at the end of the 900's, indicates that but little polished black on white ware could have been made in that early period. Our figures are necessarily incorrect in proportion to whatever small amount of polished black on white ware was made at that time. No more than a rough approximation of period is claimed for the figures obtained.

ing from about 1122 at the top back to about 1119. The debris itself dates in the late 900's.

Stratum 3, preponderantly of daily sweepings dates from about 1119 at the top to 1090 at the bottom.

Stratum 2, preponderantly of old debris was quickly redeposited from elsewhere. It dates from about 1090 back to 1088. The contents of the strata appear to be in general so similar to that of stratum 4 that we suspect most of it to belong to the late 900's.

Stratum 1, apparently entirely of daily sweepings, dates from 1088 back to 1084, when the portion of the east dump investigated was first used for deposition.

The total period of deposition on this dump in this portion investigated appears to have been approximately 38 years, from 1084-1122. This seems a very short period for the accumulation of such a large mound, but when one considers that the material of strata 2 and 4 are indicated by the charcoal to be old refuse hastily re-deposited, the discrepancy between size of dump and time of accumulation is not so apparent. Working from averages and proportions, as has been necessary, the dates and periods are understood, moreover, to be approximations only.

As we have no record in the section of the dump excavated of material from the period between the end of the 900's and 1084, we must suppose that some other dump or another part of this dump was in use during that period.

Further Evidence of Chaco Pottery Chronology.

The 1929 excavations included a trench cut down to the base of the back wall of Chetro Ketl, 14 feet below the present surface. Under the accumulation of sand that has drifted into the space between the back wall and the cliffs of the north side of the cañon were found charcoal, piles of ash, fragments of deerhorn, and potsherds. Percentages of types as listed for the descending levels in the table below, discounting the mixed surface debris with its small total of 5 sherds, show a consistent drop in the polished black on white prevalent in the second level. As the polished ware decreases, the semi-polished increases, although both are always present. Samples are given for representative levels.

Sherd counts taken as a test from a few Chetro Ketl rooms reveal the same combination of wares as found in the dump—rarely was one single black on white type found unaccompanied by one or more types of black on white. Counts taken from third floor fills are not to be relied upon as representative of what may have been made at any one period, however, as the present upper rooms apparently filled with debris when higher portions of the pueblo collapsed after abandonment.

TABLE VI

POTTERY STRATIFICATION IN TEST TRENCH, BACK WALL, CHETRO KETL

Depth.	Total No.	Black on white			Black on red	Corrugated		
		3	2	1		Fine	Med.	Coarse
0-2 ft. below surface	5	20 %	60 %	0 %	0 %	0 %	20 %	0 %
2-4 ft.	56	32.2	14.3	1.8	5.3	32.2	12.5	1.8
8-12 ft.	21	43.0	52.4	0	0	0	4.8	0
13-14 ft.	108	12.1	21.2	0	0.9	41.6	23.4	0

Kiva G, the east tower kiva, lined with type IV masonry and dated 1102, yields a high proportion of polished black on white sherds from the fill above the floor level, (Table VII). Semi-polished and Mesa Verde sherds are present, but there is no sherd of unpolished ware. In the sector of the Great Sanctuary examined, the uppermost stratum beneath the last used floor contains about twice as much polished as semi-polished ware, with little unpolished, (Table VII). This represents the period of the inferior late type III masonry. The next lower stratum, and an older floor level, is noticeable for its abrupt change in prevalent pottery type; the semi-polished increasing with the depth, the polished decreasing. There is no unpolished on the lowest of these three levels, the semi-polished is high in percentage, and the polished is low. In the lowest level, between the two coarse stone walls which may be of masonry I and probably belong to an earlier period of construction than the rest, the total number of sherds found make up only a small sample. In this sample, the semi-polished and the polished are equal in percentage; no unpolished is present. As the space between these walls may have been filled at the time of construction of the Great Sanctuary, the potsherds taken from that fill probably do not belong to an early period.

TABLE VII

SHERD DISTRIBUTION IN KIVA G AND SECTOR OF GREAT SANCTUARY

	Kiva G				Great Sanctuary					
			St. 4		St. 3		St. 2		St. 1	
Chaco	No.	%	No.	%	No.	%	No.	%	No.	%
Black on white, polished	143	45.5	524	49.0	512	48.0	80	20.9	23	37.1
Black on white, semi-polished	36	11.5	236	22.0	302	28.1	254	66.5	24	38.7
Black on white, unpolished	0	0	10	0.9	2	0.2	0	0	0	0
Mesa Verde black on white	14	4.5	78	7.2	18	1.7	0	0	1	1.6
Kayenta black on red	16	5.1	62	5.8	35	3.3	26	6.8	0	0
Black on red, smudged int.	2	0.6	82	7.6	145	13.6	12	3.4	0	0
Corrugated, fine	28	8.3	64	6.0	44	4.1	9	2.4	4	6.5
Corrugated, medium	36	11.4	11	1.0	9	0.8	0	0	10	16.2
Corrugated, coarse	25	7.9	3	0.2	0	0	0	0	0	0
Unclassified, black on white	16	5.1	0	0	0	0	1	0.2	0	0
TOTAL	314		1070		1067		382		62	

Among the boulders of the talus beneath the cliffs to the west of Pueblo Bonito was found a rock shelter walled in at the back and on one side with crude masonry. The floor, when cleared of debris, showed the remains of a fireplace marked by ashes and fragments of charcoal. Two of these fragments, measuring slightly over an inch across but with the exterior rings present, dated with perfect certainty at 1103 A. D. This was evidently the year when these branches were brought in for the last hearth fire. The potsherds in the lower debris were of black on red, corrugated ware, and polished black on white.

The only burial located during the several periods of excavation of the east dump was found in level 11, section 5, just below the top of stratum 3. With the flexed body were funerary offerings of pottery, all polished black on white ware. The exact date of this interment is unknown; this level at the top of stratum 3 is dated at 1119+; (See discussion of stratum 3), but it is possible that the burial is intrusive and of a later date. In either case, it evidently represents a period not earlier than that of the surrounding debris, and hence indicates the type of pottery being made at 1119 or later.

Summary of Pottery Succession

These various pieces of evidence strengthen the dump data leading to the conclusion that the fine polished black on white ware was the most popular type during the last years of Chetro Ketl occupation. Semi-polished and unpolished black on white wares appear to have been made at the same time, but according to the potsherd contents of the dated dump strata, they were more prevalent before polished black on white gained its ascendancy. It is possible that the three types were actually successive in evolutionary conception, but no data are yet available to substantiate such a theory. The hold-over of the cruder wares into the period succeeding that of their predominance is illustrated by the dump material. The semi-polished black on white ware was prevalent at the end of the 10th century, as illustrated by the material of stratum 4. The polished black on white was predominant from about 1084 when stratum 1 was begun, to about 1122, when stratum 4 was completed. How long before or after these dates this pottery may have been made, we cannot yet say.

Part III

Discussion of Weather as a Factor in Chaco Prehistory

1. Climate and Topography in the Prehistoric Chaco.

When we consider the requirements of the probable prehistoric population of the Chaco, it is at once obvious that the climatic conditions prevalent today certainly did not obtain during the time of pueblo occupation. With the exception of half a dozen cottonwood trees, some scrub juniper of the mesas, and a heavier stand of juniper ten miles up the cañon rim, no timber of any sort is to be found here at present. Yet the former inhabitants used thousands of logs and poles in their ceilings, for kiva pilaster supports, and for firewood. We know that they had pine, Douglas fir, piñon, juniper, cottonwood, brush, and water reeds because we find them in the structures. Water was necessary for mixing mortar for building as well as for household use. Today there is water in the wash only immediately after storms on the continental divide; building on such a scale as that of the ancients could not now be attempted unless numerous dams or wells were developed. Drinking water for the occupants of a single pueblo could not be obtained at present.

Early Water Supply. In 1849 Simpson [25] found the Chaco arid, and he believed it incapable of supporting agriculture, although he thought it had been cultivated in prehistoric times.

The wash which now keeps the water table low and cuts many feet laterally from the cañon floor each summer is of recent origin. It is possible that the Chaco wash may have been cut down and refilled more than once since the desertion of the pueblos. It is probable that a small surface stream provided water for drinking and for mortar mixing during the period of pueblo occupation, for we find water reeds used as packing for the inner kiva walls.

Prehistoric Chaco Forests. In 1923 Douglass photographed and took increment borings of two pines living under minimal conditions of existence on the south mesa three miles from Chetro Ketl. Their outer rings could scarcely be read. These trees have been cut since for wood.

Another small group of modern pines is found at the head of the Chaco, on the Continental Divide. With the evidence of these modern pines and of the juniper on the mesas, it appears probable, according to

25. Simpson, 1850.

Douglass and Pearson,[26] that a forest of pine, Douglas fir, and piñon once existed on the Continental Divide. A sparse stand of pines, piñons, and junipers scattered over the mesas and trailed down the side cañons. The altitude of 6000 to 7000 feet is but slightly low for dense stands of pines, and in watered cañons where the soil is sandy, trees may follow cañons to altitudes some thousand feet lower. We have cited the evidence that the Chaco was formerly a flowing stream, beside which grew the water reeds used in lining inner kiva walls.

It is possible, although hardly probable, that the Chaco people might have carried their building logs in to the cañon from the region of the modern forest 60 miles northeast, but in the charcoal of their firewood we have a strong evidence of the existence of a Chaco forest. In the debris of the dump we find the most prevalent type of charcoal to be piñon branches. Pine and occasionally Douglas fir branches are represented; there is a considerable amount of juniper and some brush. If juniper wood were at hand, piñon, pine, or fir branches would never have been carried sixty miles, or even half that distance, for firewood. We are thus brought to the conclusion that at least on the Continental Divide and probably to some extent in the cañon and on the mesas an evergreen forest did exist.

If forests formerly covered the Chaco area, even sparsely, the climate must have been slightly moister, cooler or both than is the region today. Pearson has published temperature records from a forest and from adjoining treeless areas.[27] In the yellow pine zone, away from mountain influences, he finds the mean maximum temperature averaging from 2 to 3 degrees lower in the open. A number of European investigators, quoted by Raphael Zon,[28] likewise of the Forest Service, contend that their widespread experiments prove an increase of anywhere from 3 to 28 per cent of rainfall in forested areas over those which are open. American investigators side both for and against the Europeans, but it is generally conceded that the presence of forest might increase rainfall at least slightly. If this be so and the Chaco be supposed to have been partly forested during the period of prehistoric occupation, it is possible that the pueblo farmers could have counted on slightly more rain than falls today.

More important to them than the amount of rain would be the conservation of moisture assured by the forest ground cover. This would keep the stream flowing but would prevent flood waters from running off in a torrent and cutting down the stream bed, which would in turn lower the water table and leave the surface soil too dry for profitable farming. To a group

26. Director Southwest Forest and Range Experiment Station, Tucson, Arizona.
27. Pearson, 1931.
28. Zon, 1927.

living under minimal subsistance conditions on a forest border, as this region would have been even under the most favorable conditions conceded, natural drouth and drouth consequent upon soil denudation may be injurious or fatal. The drouth of soil denudation is apparent in the barrenness of the modern Chaco. If the rain which falls upon the Chaco region today were conserved instead of lost through immediate drainage of the eroded soil and deeply cut washes, there would be neither lack of water nor of vegetation.

Forest Disappearance. The study of modern forest recession and of its causes in the southwest must be considered in dealing with the problem of existence and disappearance of a prehistoric Chaco forest.

In traveling westward on the Cuba-Farmington highway which crosses the Continental Divide north of the Chaco, one finds ridges covered with piñon and juniper. This lower forest stretches over an east-west strip approximately 20 miles across. Shortly after entering this area one notices that among the standing trees many are dead or dying, and many dead trees lie on the ground. In rough percentages the proportion of dead and dying might be given as from 25 to 75%. As dead piñon trees are known to stand but twenty years or less, the recency of this phenomena is apparent.

As the road drops to the desert (Fig. 4, Plate 9) one finds the forest decreasing over an area about twenty miles in width. Percentages of dead trees rise to 90, and finally there are no living trees to be seen; the dead lie on every low hill top and the lower areas are bare. As soon as these have decayed, no evidence will be left to indicate that the border once reached this point.

This is a forest which appears to be withdrawing its borders back toward the continental divide. If a forest formerly existed on the divide where it heads the Chaco and from there trailed a thin border thirty miles down the cañon to the region of pueblo concentration, it is clear that today we might have no evidence left of that forest except for the few pines found alive and the thousands of beams used in the pueblos.

An answer to the general question of why timber type recedes is summarized as follows:

"Timber [29] types may be pushed back due to one or more of the following factors, working alone or in combination: Reduced precipitation, extreme fluctuations in the annual distribution, seasonal distribution or form of precipitation; repeated severe fires; calamities such as windfall followed by insect attacks, or insect attacks independent of windfall; insect

29. Quincy Randles, Assistant Regional Forester in charge of Forest Management in the Southwestern Region.

attacks following cutting; winter injury; excessive runoff of precipitation due to reduction in herbaceous vegetation.

"Usually when a timber type is thinned down for any reason the maintenance of the type on areas somewhat adverse is difficult due to the lack of so-called forest conditions. Heavy grazing of game animals or domestic animals would also have an influence in the advance or retreat of timber types, as would also the concentration of an excess number of rodents of various sorts, including those that might destroy the tree in its various life stages, or consume an unreasonable amount of the seed from the tree.

"It will be seen from the foregoing that quite a number of factors might be responsible for pushing back the timber type. Data as to whether these factors were occurring in the distant past, which would account for the possible retreat in the area mentioned (the Chaco) are of course unavailable.

". . . in other areas in the State (New Mexico) seemingly similar, it is apparent that the timber type is not holding its own. These observations, however, are based only on twenty years' experience, and during a short period, such as this, there might be a temporary reduction in the number of trees for some reason, and then later a building up process. On other areas in the Southwest it is apparent that the timber type is extending its range. This is particularly noticeable on the edge of the juniper type and in the ponderosa pine in certain parts of Arizona, where reduction of these species has extended itself within the past 40 years for over a mile, and in some cases with the juniper for many miles outside the area where seed trees are available. Juniper seeds are eaten by certain game animals and by stock and are carried by these animals for considerable distances. The type is thus being extended. This extension, however, is for the most part in natural openings where no precipitation has been sufficient so far to maintain the species. Whether this extension can maintain itself in the future is yet to be determined.

". . . we do not have a sufficient number of well distributed weather stations to determine the local variation in precipitation and other factors, and it may be that there is a much greater fluctuation in the rainfall over relatively small areas than is now imagined. While precipitation is probably one of the biggest factors involved, the other factors I have previously mentioned would in certain cases exert an influence equally as great."

Some years ago Douglass made the suggestion that where the evergreen stand was barely managing to maintain itself, the injury of wholesale and unscientific cutting of timber by pueblo people might lead to some recession of the forest borders. It seems that the amount of timber cut for pueblo beams could not permanently injure a forest, but it must be remembered that every usable tree near a village would be cut before the people

were forced farther into the forest to obtain their timber and firewood. Under such circumstances reproduction of the forest border would be impossible, and, as Randles has pointed out, the stand would maintain itself with difficulty.

We cannot say definitely that Chaco forest recession was the result of human injury. If a forest once existed and has since receded, the cause might have been any one of those suggested. It becomes apparent, however, that the existence and disappearance of a prehistoric forest is entirely possible. The presence of the few remaining modern pines, of the juniper, and of the ancient beams and firewood, indicates the former existence of that forest to be even more than possible.

In the recession of a forest the ground is denuded. Denuded land, as is frequently seen in New Mexico and Arizona, becomes cut and washed by storm waters. The water table lowers as arroyos deepen. The light surface sand begins to blow as it becomes more denuded. The Southwest offers many examples of modern gashed arroyos, twenty to thirty feet deep, in country known to have been entirely uncut when ranchers settled twenty-five years ago. Each heavy storm extends the cut at the head of the main arroyo or of its tributaries by several feet. Exactly that process is at present cutting away the banks and back into the side cañons of the Chaco itself. Denudation caused by grazing is the cause of this modern situation in some areas, but removal of the ground cover by any other agent would effect the same result. The Chaco soil is light; slight impetus would begin the work of soil erosion, sand blowing, and arroyo cutting, a process which would work backward up the cañon as it progressed.

One of the principal problems in connection with Chaco forest recession is whether in the 300 years of prehistoric occupation the dessication might have progressed far enough to make farming impossible or to leave the water supply insufficient for household consumption. Either situation would act as a local drouth in depopulating the cañon.

As may be seen in referring to the master chart at the bottom of Fig. 1, Plate 10, in which drouth periods are covered by wavy lines, there was no record of a general drouth in the early 12th century. Examination of Chaco trees, however, shows that the rings of those growing late during the prehistoric period are more sensitive, showing greater variation in width from year to year, than those growing earlier. This increase in mean sensitivity indicates that less water was available and that, consequently, the effects of dry years were proportionately worse than previously. Certainly all the forest could not have disappeared by the 12th century. The remaining trees would show the effects of decreases in water supply, but the injured forest back of the area already denuded would retreat slowly, probably over a period of centuries. The two pine trees

which may represent the last straggling remnants of a forest, we note again, were found by Douglass in the first quarter of the 20th century.

2. *Effect of Climatic Fluctuation on Chetro Ketl History*

Effect of Drouth on Desert Dwellers. Small variations in rainfall may affect minor or even major drouths on desert borders where conditions for maintenance of life are at a minimum. Such variations are of prime importance to a people, agricultural, pastoral, or nomadic, inhabiting those desert peripheries. Observation shows that sedentary people adapt themselves to deserts by the development of dry farming, while nomadic hunters and herders learn to make carefully considered group movements from one area of grassland or one water hole to another. When a drouth strikes the entire region, the desert borders will show a larger percentage of change in plant and animal life than will the better watered regions, because the life of the desert borders is subsisting on but a minimum of water under normal conditions. Climatic changes of moderate intensity and duration may bring about great suffering, migration, or even extermination of a desert people, especially if they be sedentary.

In the pueblo area where the people depended on summer rains for their agriculture, we find increasing evidence of the abandonment of villages during the most intense prehistoric drouth yet known, 1276-1299. Once a century, on the average, drouths left their imprint upon the trees later used by pueblo people in their building. Drouth effects upon agriculture would be paralleled to some extent by effect on amount of wild plant and animal life available as food for surrounding nomadic tribes. Discouraged and depleted by food shortage and hardship, the pueblo people must have found themselves at times sorely pressed by nomads who naturally turned to raiding to eke out their own meager subsistence.

Further work in tree ring studies offers possibilities in relating innovations in pottery, masonry, and other material culture developments to outside contact with drouth suffering migrants, or in relating degeneration of such arts to the hardship, hunger, and danger of local drouth.

In this desert area long drouths lasted from five to ten years, but the difficulties could be brought about by no more than two or three successive dry years, each often dryer than almost any single year of the long drouths.

Recently translated accounts of de Anza's work in New Mexico indicate that the two years' drouth of 1777 and '78, although not of sufficient dryness to be heavily scored on our climatic chart, were disastrous to Zuñi and almost exterminated the Hopi. To quote:

> "Their existence (at Zuñi) I found to be most deplorable in every particular, owing to the lack of rain in these parts for the last two years, on which chance their comfort depends, as all the crops

> they make are temporal and the failure of these has reduced the number of inhabitants to a very few, they being the most numerous in the Province, and the preceding (condition) requiring them to continue living at the ranches where they pasture their small stock, of which there is a reasonable abundance; and the others, a larger number, are in our interior pueblos, and are hoping that after the misfortunes they have suffered, the greater part of them may recover this present year through the abundant crops they now have, which will be harvested, if Divine Providence retards during this month the frosts that are accustomed to occur at this time." [30]

Anza went on to Hopi and found the villages reduced from 7,494 persons counted by Escalante in 1775, to 738 persons, 6,696 having died, joined the Navajos, gone to New Mexico pueblos on the Rio Grande, or been killed by nomadic tribes during their migrations. The seven pueblos were reduced to five, none containing over 45 families.

> "The last news coming to me as to the condition of the Moquis is that the majority of them are taking shelter with the Corina Nation—one of those inhabiting the Rio Colorado—in order to enjoy the fruits of such crops of corn and wheat as may be planted there; whence they assure me they are inclined to remove all those who do not join us, in case it should so happen that they have no rain this present year, as in previous years, because it is impossible for them to continue to live in their old pueblos due to the lack of seed of every sort, and even stock, which was abundant, since they assure me that the many thousands of sheep are now reduced to a few hundred, because they ceased caring for them as before so that they could join themselves with the Apaches."[31]
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> "The causes which have contributed to the extermination of these pueblos of the Province, including all its natives, have been hunger and pestilence, the first because it has not rained since the year '77, and from that has resulted the second, to which may be added the war cruelly made upon them by the Utes and Navajos."[32]

Climatic Variations as a Factor in Chetro Ketl History.

The extent of climatic variations upon the cultural history of any sedentary group is a question to be settled only by a mass of evidence. When Chetro Ketl and other pueblos have been completely excavated, dated, and compared, generalizations concerning this problem should become apparent and offer some basis to the general question of fluctuation in southwestern pueblo culture. With the material at hand it is possible to review

30. Colonel Juan Bautista de Anza, Governor of New Mexico, Diary of his Expedition to the Moquis in 1780, Ralph E. Twitchell, 1918, p. 27.

31. *Ibid*, p. 17.

32. *Ibid*, p. 36.

the trends of Chetro Ketl history in comparison with the pulsations of climate and so to investigate the possibility of directional reactions between culture expression and the material well-being of the people. The dates to be considered will be taken from Plate 1. The climatic record to be considered is seen in the master chart drawn beneath the diagram of Chetro Ketl building periods, Fig. 1, Plate 10. Correlation of dry years, building periods, and dump stratification is found in table VIII.

The site of Chetro Ketl was apparently occupied and built upon at least by 945 A. D., as discussed previously. Una Vida was occupied at least as early as 864 and Peñasco Blanco at least by 898 A. D. Masonry I was used in their architecture. At present we can but guess at the pottery of the period. With dated evidence from the dump that the period when polished ware was predominant was toward the end of the 1000's, and that the semi-polished was predominant between 960+ and 1020+, it appears possible that the crude unpolished black on white was largely in use at an early period, perhaps the latter half of the 9th and the first half of the 10th centuries.

It is apparent that the drouth which began in the Chaco in 899 and left its heavy effect upon the trees between 900 and 907 did not drive the people from the cañon, but until more dating has been done in this early period it is impossible to determine to what extent they were affected.

Between 991 and 1005 wet and dry years alternated, the period culminating in an exceedingly dry year at the latter date. In the next decade, 1014 and 1019 were dry, but except for these years there was no marked lack of rain until 1035, when a six-year drouth set in.

The building period of masonry II is found to have begun just before the beginning of this drouth; it continued to 1070. Talus site I, a small structure of a few rooms surrounding kivas, (Fig. 2, Frontispiece), was built against the cliff to one side of the main growing structure of Chetro Ketl. Beams from a masonry II room in the talus site date at 1038. The first floor rooms of the back section of Chetro Ketl itself probably date at about the same time; one room has been excavated and dates 1035.

During this period the pueblo took on the shape of a squared C, the typical Chaco ground plan. As we find no cessation of activity during the drouth, we are forced to believe that ground cover was present in the Chaco drainage to conserve sufficient moisture so that the soil remained tillable and the stream running with water for drinking and for mixing mortar. After the drouth good weather prevailed until 1067 and '68, both very dry years.

The period of masonry II merged into that of masonry III, the two overlapping between 1062 and 1070. The period between 1062 and 1090 is marked by generally propituous weather except during 1067 and '68,

mentioned above, and the somewhat dry years of 1070, 1072, and 1074. Chetro Ketl reached the height of its development of ceramics and architecture during the period of masonry III. Between 1084+ and 1088+, represented by stratum I on the dump, debris was not deposited and consequently we lack evidence of rebuilding operations. The later years 1088+ to 1090+, appear to have witnessed the razing of old structures and the clearing away of old debris to make place for new buildings. These years are represented in the dump by stratum 2. The number of re-used logs found in the east wing structures of this period in Chetro Ketl check the evidence of reconstruction being carried on at this time.

Chetro Ketl not only reached its height in this period; it began its decline. The inferior type III masonry which was contemporaneous with superior type III was the first of the succeeding series of poor types of stone work. Troubles with marauders may be indicated in closed outer doors filled with poor masonry III. Perhaps the first difficulty with the supposed decreasing water supply dependent on increasing deforestation was exasperating their priests and turning public attention toward more fervent and frequent ceremonies for rain, more prayers in the kivas, more dances in the plaza. Perhaps their culture unit had merely reached its peak and was pausing a moment before it slipped into marked degeneration. The probability is that each of these factors contributed to decline.

No building dates have yet been found between 1090 and 1099, when the next period began. 1099 and 1101 were both very dry years and witnessed little building, but in 1102, many additions were made. Between 1110 and 1121 there were no dry years. 1125 was the last dry year during which we believe the pueblo could have been occupied. As previously stated, we do not yet have a final date on Chetro Ketl. The structures of this last period were of types III, IV, and V masonry.

Between 1090+ and 1119+ there was comparatively little clearing away of old debris, as shown by the preponderance of daily sweepings running high in polished black on white ware in stratum 3 on the dump. There was some re-dumping, however. Toward the top of this stratum in the west-central pit and in the east trench are found pieces of charcoal dating in the late 900's and early 1000's. The latter three years of dump deposition, 1119 to 1122, are characterized by a great deal of secondary dumping of debris of the early period. The architecture we know for the last building period shows, moreover, a high proportion of old reused logs taken from various periods and incorporated into structures definitely dated in the early 1100's.

At present we are not attempting to set forth any unquestioned reason for the abandonment of the pueblo or of the Chaco, but several explanations suggest themselves for consideration. We lack evidence that this pueblo

or the others were deserted or depopulated as the result of pestilence or warfare, but filled in doors and lack of outside entrance indicate that the encroachments of nomadic tribes may have become increasingly troublesome and necessitated migration. Or the culture may have died a gradual and natural death. This seems improbable, however, when we consider that their period of highest cultural development was at the end of the 1000's and that the cañon has so far shown no building after 1130. The fact that no skeletons and little household goods are found intact in any rooms suggests that the people left and took their possessions with them. Moreover, as all the Chaco pueblos appear to have been abandoned largely at the same time, it would seem that the movement was general. On four pueblos the latest dates of 1123, 1124, 1127, and 1122+, fall into close alignment, (Fig. 1, Plate 10).

Local drouth caused by deforestation having reached a point beyond which water conservation was impossible may have begun cutting the arroyo. This would lower the water table so that farming would be difficult and water scarce for building and for drinking. Such a situation might force a people out of a thickly populated district. Should any catastrophe have cut off their water supply they would have been compelled to leave.

From the above comparison of building periods and climatic fluctuations it is apparent that the Chaco builders were not turned from their work even by the long drouths of 900-907 and 1035-1041; the environment must have been such as to minimize the effect of these drouths. If Chaco building continued through the drouths, dry periods must not have engendered any tragedies in the prehistoric Chaco comparable to those reported by Anza for the Hopis and the Zuñis in 1787. There is no general long drouth known for the early part of the 12th century; if a local drouth was produced by denudation it could have been augmented by nature only with single dry years. Even though general drouths had not affected the Chaco people previously, an unalleviated continuous dearth of water resulting from denudation might not have been withstood. The question is whether if denudation had not advanced far enough to make a disaster of the drouth of 1035 to 1041, it yet could have progressed so far in the next one hundred years as to cut the wash, lower the water table, and so render existence in the area difficult. Our knowledge of modern southwestern washes cut 25 feet in from 30 to 50 years provides a basis for supposing that such a cut could have developed in twice the time in ancient days. Direct evidence for the prehistoric situation is difficult to obtain, but as one of the suggested factors for Chaco depopulation or deforestation must be considered. That it is but one of the contributory to abandonment of the region and probably not the most important is indicated by the fact that Kinya-a, near Crown Point and 30 miles south of Chaco cañon, and

Kinbiniola, located on a wash draining from the south, were abandoned with the other Chaco pueblos. Chaco deforestation would have effected them, but not, one might suppose, to the extent of causing a migration.

Topographic and weather studies of the Chaco are in progress, and with further study of pueblos of this cañon and of surrounding areas, within the next few years may considerably clarify some of the problems whose solutions we only suggest at the present.

TABLE VIII

CORRELATION OF CHETRO KETL BUILDING PERIODS, DUMP STRATA DEPOSITION, AND CLIMATE

Climate Dry Years	Masonry Periods. (as known in 1933)	East Dump Strata Deposition
	A. D.	Ca. 1122 Stratum 4
1121		1119 (old debris)
	1116+ Masonry Late inferior III, IV, V.	Stratum 3 (Daily sweepings)
1099, 1101		
	1099	
1090, 1091	1090 Masonry III, Superior and inferior	1090 Stratum 2
1074		1088 (Old debris)
1072		
1070	1070	1084 Stratum 1 (Daily sweepings)
1067, 1068		
	1062 Masonry II	
1035-1041		
	1030	
1119	Masonry I	
1114		
1005		
997		
995		
993		
991		
980, 981		
972		
954		
	945	

Summary

The problem of fundamental interest in this study of Chetro Ketl lies in the significance of its dated prehistory. The techniques employed in obtaining this history are: 1. chronologies and records of climatic variations studied by the Douglass system of tree ring analysis, and 2. supplementary data on relative dating and on material culture trends as found in styles of superposed masonry and in types of pottery taken from the refuse mound. The dating of charcoal fragments in the dump as a means of certifying the overturning of some strata, suspected from statistical study of potsherd content and from soil composition, is a new application of tree ring study to archaeological problems.

Briefly summarized, Chetro Ketl history is found to divide itself into three periods, of which the first and at present the least known is the longest. We recognize the existence of this period through discovery of timbers the cutting dates of which fall between the years of 945 and 1030. These beams were subsequently re-used in walls of later construction. No walls of the first period have yet been uncovered at Chetro Ketl, as deep excavation is only begun, but logs of the same dates are found to come, consistently, from walls of crude masonry I in other Chaco pueblos. The pottery of the period, known from sherds thrown out with fireplace charcoal and other refuse which was later moved onto the east dump, consisted principally of three types of black on white and of corrugated wares. Of the black on white wares, the semi-polished was prevalent. The polished ware, second in proportion, was probably a recent development at that time, for it became the most common type during the second period.

The second period, 1030-1090, was marked by rapid pueblo growth. Masonry was excellent. Between 1030 and 1070 the masonry was that described as type II. Pottery contemporary with it in this pueblo is unknown; it is not represented by any stratum of that section of the east dump which was studied. Another dump or another portion of the east dump was evidently used for deposition during this time.

By 1062 masonry III was already in use. Between 1062 and 1070 both types II and III were employed for construction; after that time masonry II was dropped and masonry III continued. Between 1060 and 1090 extensive re-modeling, re-building, and new additions resulted in the growth of Chetro Ketl on the ground plan as we know it today, with the exception of the few additions made in the following period. Polished black on white ware was prevalent, although the semi-polished and the unpolished were

still made. The entire 60 year period appears to have been the most prosperous and flourishing of Chetro Ketl history.

The third and last main period, 1099 to 1116+, was brief, a period marked by architectural degeneration. (Although we yet have no dates between 1090 and 1099, it is presumed that the building was carried consecutively from the one period to the other and that further work will yield dates within those years.) Three types of masonry were used in the third period, but workmanship was not equal to that of the second period. Polished black on white pottery remained prevalent, the other types still being made. Chetro Ketl was probably deserted about 1020; we now have no beam dated after 1116 from its walls. Re-occupation of the abandoned village by some small migrating group may be indicated by the last stonework raised, masonry VI, which bears little resemblance to typical Chaco masonry types. It is conceivable that this masonry may represent only the degenerate work of a small native group who lingered on in their old home, but the fact that the Great Sanctuary bench was finally re-lined in this style rather suggests the work of new-comers.

There is no indication that the abandonment of the Chaco pueblos was the result of a war of extermination or of pestilence. We do know that the two long drouths which fell within Chaco history made little impression on Chetro Ketl building activities. If a prehistoric pine forest extended into the Chaco, the ground cover must have been sufficient to conserve all moisture available and hence to protect the constant water supply of the thickly populated area. That such a forest existed is indicated not only by the high consumption of logs in Chaco pueblo building, but also by the preponderance of piñon and pine branch charcoal deposited with refuse from the household fires on the dump. It is significant that two modern pines remained a few years ago in the dry and gashed cañon. One factor entering an explanation of the abandonment of the Chaco is increasing aridity consequent upon increasing deforestation, possibly inaugurated by careless cutting and the impossibility of reproduction. It is unlikely that the Chaco was ever heavily forested, and thin forest borders are known to injure easily and may retreat rapidly.

Roberts, in tracing early southwestern movements, suggests that people from the Piedra district were the first to be forced out by the menace of maurading tribes, possibly mixed Athapascan ancestors of the Navajos, who were pushing into the southwest from the northeast. Some of the people drifted in to join the Chaco communities. Later, people from Johnson Cañon in southwestern Colorado deserted their homes; some went south into the Chaco. Still later, parties from Montezuma Valley and McElmo Cañon scattered, some finally joining the Chaco people. The Chaco was the first of the large pueblo centers to fall, however, in spite of

these accessions of population from time to time. Its demise was followed by that of Mesa Verde, and considerably later by that of the Kayenta settlements.[33]

Direct evidence of the infiltrations of people from abandoned districts into the Chaco is at present either lacking or un-interpreted at Chetro Ketl. It is possible that the flourishing expansion of the second period may have been effected by acquisition of vigorous new blood whose energies went into pushing forward typical Chaco material culture rather than into imposing their own former characteristics onto it. Relative amalgamation of small intruding bands and their adoption of the culture of their hosts has been illustrated at Hopi in historic times. If an archaeologist should excavate Walpi and Hano, actually one architectural unit in spite of the two names, it would be difficult to find criteria which would indicate that the one end of his village was native while the other belonged to refugees from the Rio Grande. Further work in the Chaco may distinguish more direct evidence of foreign settlers than we are now able to report.

In corroboration of the increasing pressure from nomadic tribes mentioned by Roberts, we have several evidences of protective measures taken at Chetro Ketl during the second priod. Outer doorways in walls of masonry II and III were closed with matched or with a later type of masonry. A corridor with wide closely-spaced windows, approximating a collonaded cloister across the front of the central section of the pueblo during the period of masonry III, was later converted into rooms with closed windows. Across the open front of the plaza a curved double wall was built to connect the lateral wings of the pueblo. The space between the walls was later filled and covered with a line of rooms. This completed the village enclosure, into which excavations have yet disclosed no outside entrance.

The exact dating of Chetro Ketl Prehistory provides us with the following significant observations:

1. The first period of Chetro Ketl history was long and apparently more or less uneventful. At present it is the least known of the Chetro Ketl periods. The second, shorter, was a period of rapid development of fine masonry, of extensive pueblo expansion, and, during the latter years, of fabrication of the best pottery developed in the Chaco. The next period was likewise short, a relative degeneration of Chaco culture shortly before the Chaco was abandoned. The final structures of crude masonry in the last period may indicate a small re-occupation of the abandoned pueblo.

The refuse mound although deep, represents only about 38 years of

33. Roberts, 1931, pp. 12-13.

accumulation, partly of older re-dumped material, in the section investigated.

2. A forest border probably trailed down the Chaco cañon from the continental divide, 30 miles eastward. Besides providing building material and firewood of pine, Douglas fir, and piñon, it conserved moisture enough so that the activities of the people were not curtailed by water shortage even during the drouth of 1035-1041. Historic accounts of the disastrous effects of a two-year drouth which almost exterminated the desert pueblos of the Arizona Hopis contrast with the apparent lack of serious effects of the seven-year drouth which inaugurated the golden age of Chetro Ketl.

3. The effects of drouth, extreme on a desert, may be mitigated in a forested area, but if that forest should disappear the local effects of any drouth would be increased in proportion to the decrease of local ground cover and to the increase in washes cutting the soil.

4. In an area of minimal conditions for existence, a desert or a desert border, climatic fluctuation, modified by topography, may function as a limiting factor in culture development. Drouths may necessitate group migrations, cause a temporary decline in culture, or threaten extermination. It is doubtful that periods of normal or of excessive precipitation are equally effective as a partial factorial determinant of culture trend, except relatively, insofar as they are non-restrictive. Certainly there is no indication in Chaco tree ring records of rainfall in excess of the average during the most flourishing period of Chetro Ketl history. Present data point to deforestation and consequent increase of aridity as a factor in the culture decline and the final abandonment of Chetro Ketl, but other factors likewise contributory to the disappearance of Chaco culture comprise a problem for further investigation.

Protocols

DATED CHETRO KETL TREE RING SPECIMENS
1930-1933

Specimen number	Room	Floor	Masonry	Date Inner-Outer	From end	Type	Radius in inches	Certainty
CK 1	4	2	Inf. 3	965-1053 A. D.	10-15	¼ sec.	3½	8
2	4	2	Inf. 3	1012-1059	10-15	sec.	1¾	9
5	4	2	Inf. 3	1035-1062	10-15	sec.	2	10
9	4	2	Inf. 3	986-1072	1- 5	¼ sec.	3¼	10
10	8a	1	Inf. 3	986-1068	1- 5	sec.	3½	10
13	Kiva A		Inf. 3	1030-1070	1- 5	sec.	1½	8
14	Kiva A		Inf. 3	961-1070	1- 5	sec.	1½	10
24	Kiva A		Inf. 3	966-1067	1- 5	¼ sec.	4¼	10
25	Kiva A		Inf. 3	1007-1069	1- 5	½ sec.	1½	9
27	8	1	Inf. 3	1035-1074	end	sec.	3½	10
30	8	1	Inf. 3	1001-1061	5-10	core	4	10
33	40	3	2	1011-1051	1- 5	sec.		8+
34	40	3	2	-1052	1- 5	sec.	1½	8
36	43	3	2	820- 937	far	broken sec.	4	10
37	44	3	2	940-1049	1- 5	sec.	3¼	10
40	43	3	2	1019-1052	end	sec.	1½	9
42	43	3	2	965-1057	1-10	¼ sec.	5½	9+
53	Kiva G (buttress)		5, 4	960-1103	end	core	5½	10
54	Kiva G (buttress)		5, 4	977-1100	end	core	2½	10
55	Kiva G (buttress)		5, 4	947-1035	end	core	5	8
56	Kiva G (buttress)		5, 4	1008-1052	end	core	2¾	9
57	Kiva G (buttress)		5, 4	1057-1099	end	core	2	10
58	Kiva G (buttress)		5, 4	1062-1099	end	core	2½	10
61	Kiva G (buttress)		5, 4	960-1100	end	core	3½	10
63	Kiva G (buttress)		5, 4	975-1051	end	core	4	9
64	2	2	Inf. 3	991-1037	end	core	1½	10
65	44	3	2	915-1038	end	core	5	10
66	2	2	Inf. 3	927-1050	end	sec.	4¼	10
67	40	3	2	990-1053	end	sec.	3¾	10
68	2	1	Inf. 3	950-1039	end	sec.	4½	10
70	Kiva G (buttress)		5, 4	1037-1075	end	sec.	2	8—
72	Kiva G (buttress)		5, 4	940-1050	end	sec.	3½	10
73	48	3	2	991-1059	end	⅛ sec.	6½	10
75	48	2	2	976-1038	end	½ sec.	3½	8
76	48	2	2	1025-1052	end	sec.	1½	8
80	48	2	2	-1053	end			9
81	48	2	2	1023-1053	end	sec.	1¾	8+
82	48	2	2	923-1053	end	1/3 sec.	4½	9
83	48	2	2	998-1039	end	sec.	2¼	9
84	48	2	2	961-1053	end	sec.	4	10
85	48	2	2	972-1052	end	sec.	3¾	8
89	46	3	2	-1053	end	sec.	1	8—
94	46	3	2	962-1061	end	sec.	4½	10
95	46	3	2	-1033	end	sec.	3¾	10
96	46	3	2	1002-1063	end	sec.	3½	9

Specimen number	Room	Floor	Masonry	Date Inner-Outer	From end	Type	Radius in inches	Certainty
99	43	2	2	-1037	end	core	3½	10
101	46	2	2	-1043	end	½ sec.	4½	10
102	46	2	2	969-1041	end	¼ sec.	3½	10
103	44	3	2	960-1052	end	sec.	4¼	10
104	44	3	2	964-1059	end	½ sec.	5	10
105	44	3	2	900-1007	end	sec.	2½	10
107	44	3	2	956-1008	end	¼ sec.	2½	10
109	44	3	2	-1009	end	sec.	2	10
110	44	3	2	983-1009	end	sec.	2	10
111	44	3	2	946-1000	end	sec.	2¼	10
112	44	3	2	938-1000	end	sec.	2¼	10
113	44	3	2	959-1000	end	sec.	2¼	10
115	44	3	2	957-1009	end	sec.	2½	10
116	44	3	2	951-1002	end	sec.	2¼	10
117	44	3	2	957-1047	end	sec.	2¾	10
118	44	3	2	918-1020	end	sec.	2	10
121	44	3	2	979-1048	end	sec.	2¾	10
123	44	3	2	1004-1038	end	sec.	1⅛	10
126	Kiva G (buttress)		5, 4	990-1049	end	sec.	2½	10
128	8a	1	Inf. 3	993-1061	end	core	4¾	10
129	1	1	Inf. 3	1048-1063	end	sec.		10
131	1	1	Inf. 3	1061-1102	end	core	3¼	10
132	1	1	Inf. 3	960-1052	end	core	5¼	10
135	1	1	Inf. 3	955-1038	end	sec.		10
136	Kiva G (buttress)		5, 4	951-1048	end	core	2¾	9
137	Kiva G (buttress)		5, 4	957-1097	end	core	2½	10
138	Kiva G (buttress)		5, 4	956-1066	end	sec.		10
139	Kiva G (buttress)		5, 4	-1049				10
140	101	2	2	920-1049	end	broken sec.	8	9
143	42	3	2	1003-1066	1- 5	sec.	5⅛	8
144	48	2	2	955-1038	end	core	1¼	10
146	43	2	2	972-1029	1- 5	sec.	4½	10
147	43	2	2	987-1029	end	sec.	3½	10
148	31	2	Inf. 3	987-1031	1- 5	½ sec.	2¼	9
149	53	2	2	955-1042	end	core	4¼	9
150	53	3	2	997-1063	1- 2	sec.	3½	8
151	53	2	2	996-1040	end	sec.	2	10
153	53	3	2	1002-1047	1- 5	sec.	2	10
154	53	2	2	1013-1040	end	sec.	2½	9
155	53	3	2	1013-1051	end	sec.	2½	8—
156	47	3	2	926-1038	end	core	5½	10
157	44	3	2	974-1043	end	core	4	10
158	44	3	2	938-1040	end	core	3¾	10
159	42	2	2	978-1028	5-15	core	4¾	10
160	48	2	2	947- 994	far	sec.		9
163	48	2	2	940-1053	1- 5	sec.	3	8
163a	48	2	2	-1003	far	¼ sec.	4	10
164	48		2	967-1024	1- 5	sec.	2¼	9
165	47	3	2	966-1037	1- 5	sec.	4	9
166	42	2	2	952-1038	end	¼ sec.	4⅛	10
167	49	2	2	1005-1038	end	¼ sec.	5	10
168	Kiva G (buttress)		5, 4	-1098	1- 5	½ sec.	2¼	10
169	Kiva I		Inf. 3	1056-1064	far	sec.	2	8
170	Kiva I		Inf. 3	1061-1083	far	sec.	2	9

Specimen number	Room	Floor	Masonry	Date Inner-Outer	From end	Type	Radius in inches	Certainty	
171	Kiva I		Inf. 3	1051-1086	far	sec.	1½	9	
173	Kiva I		Inf. 3	1053-1074	far	sec.	1½	8	
174	40	3	2	888-1054	end	½ sec.	5½	9	
175	43	2	2	952-1033	end	core	4½	10	
301	27	2	4	1049-1102	end	½ sec.	3	9	
302	27	2	4	1053-1102	end	sec.	2¾	9	
303	27	2	4	1027-1116 pair	end	¼ sec.	3½	10	
306	27	2	4	999-1092	1- 5	sec.	4¾	10	
308	27	2	4	975-1060	1- 5	core	3¾	9	
309	27	2	4	996-1099	1- 5	core	4¼	9	
310	35	2	4	987-1067	far	sec.	5	9	
313	35	2	4	916-1080	5-15	broken sec.	4¼	10	
314	35	2	4	1035-1103	end	sec.	5½	10	
316	Kiva G (pilaster support)		5, 4	847- 911	ca. 200	core	3⅛	9	
319	Kiva K		Inf. 3	999-1099	1- 5	core	4	9	
321	35	1	Inf. 3	998-1057	5-10	sec.	3¼	9	
322	35	1	Inf. 3	996-1068	end	sec.	3⅜	10	
323	38	1	Inf. 3	1026-1102	end	sec.	6	10	
324	38	2	Inf. 3	1000-1073	end	sec.		9	
325	103	2	2	864- 925	far	sec.	4	9	
326	103	2	2	954-1018	1- 5	sec.	4	10	
327	101, 102	2	2	952-1026	far	core	3¼	9	
330	Kiva H		Inf. 3	898- 931	ca. 200	sec.	2⅜	9	
331	Kiva G (pilaster support)		5, 4	643- 953	ca. 150	½ sec.	9½	10	
332	27	2	4	1061-1102	end	pieces	2	9	
335	40	2	2	944-1037	end	core	3⅜	8	
336	39	2	2	960-1051	end	core	4⅛	9	
337	40	2	2	990-1038	end	core	3¼	10	
341	48, 50	2	2	983-1054	end	sec.	1¾	8	
347	37	3	2	974-1028	far	½ sec.	4½	10	
348	57	3	2	989-1051	end	sec.	4¾	9	
353	58	2	2	942-1040	end	core	3	8+	
355	54	3	2	995-1050	ca. 10	½ sec.	4	10	
356	53	2	2	981-1043	end	½ sec.	4⅜	9	
357	59	2	2	936-1048	end	broken sec.	3¼	8	
361	59	3	2	1017-1060	end	sec.	1½	10	
362	59	3	2	900- 945	end	sec.	2	8	
369	4	2	Inf. 3	960-1056	10-50	sec.	4½	9	
371	Talus rock shelter			1038-1101	end	sec.	1⅛	10	
372	shelter			1029-1101	end	sec.	1½	10	
521	Kiva G		4, 5	834-1002	ca. 100	sec.	12	9	
522	Kiva J		Inf. 3	771-1039	far	sec.		10	
531	64	4	Inf. 3	970-1072	end	core		10	R. L.
533	64	1	2	998-1038	end	core	3	10	
534	64	1	2	970-1038	end	core	5	10	
559	55	1	2	925-1020	5-15	sec.	4	8+	
				Talus Site I					
600	3	1	2	996-1024	end	sec.	1¼	8	
602	3	1	2	982-1032	end	sec.	1	8	
603	3	1	2	998-1029	1- 5	sec.	1⅞	8	
604	3	1	2	978-1030	1- 5	sec.	2	8	
605	3	1	2	962-1019	10-20	sec.	2⅝	9	

Specimen number	Room	Floor	Masonry	Date Inner-Outer	From end	Type	Radius in inches	Certainty
606	3	1	2	958-1032	end	sec.	1½	8
607	3	1	2	856-1018	10-20	sec.	3	8+
608	2	1	3	959-1076	1- 5	sec.	3½	8
609	2	1	3	998-1066	5-10	sec.	4⅝	8

FOOTNOTE: The above table lists all usable dates obtained on wood removed from Chetro Ketl. In this dated group, 59.2% of the collection, are included only those from specimens carrying a record long enough and sufficiently clear to be marked 8 or above in certainty. The remaining 40.8% were specimens whose date carried some element of doubt and hence were marked with a certainty of only 7, specimens too short, erratic, or complacent for dating, and of a small number of pieces of cottonwood or of juniper, which were undatable. Charcoal taken from the east dump is listed in Protocol 2.

"Masonry" numbers correspond to the types described under that heading in the text. "Inf. 3" indicates "inferior type 3" masonry. "S 3" indicates "superior 3" masonry. "From end" refers to the number of rings estimated to be missing from the exterior of the specimen. "Type" designates the specimen as a section of a log, a fraction of a section, or a core.

DATED SPECIMENS FROM OTHER CHACO PUEBLOS

Specimen number	Room	Floor	Masonry	Date Inner-Outer	From end	Type	Radius in inches	Certainty
Hungo Pavi								
1			4	966-1004	end	sec.	2 1/5	9
3			S 3	979-1048	far	sec.	4¼	8
4			S 3	990-1064	end	¼ sec.	5¼	9
5			S 3	975-1053	end	sec.	5⅞	9
6			S 3	1005-1063	1- 5	½ sec.	4 4/5	9
7			S 3	938-1059	1- 5	½ sec.	4	10
Kinklizin								
1			4	1038-1084	end	sec.	1¼	8
Kinya-a								
1			4	1038-1097	5-10	¼ sec.	3¼	10
2			4	1061-1103	1- 5	½ sec.	2½	10
6			4	1061-1106	end	sec.	1¼	9
7			4	1069-1106	end	sec.	1¾	10
8			4	1060-1106	end	sec.	1⅝	10
9			4	1040-1106	end	sec.	1⅜	10
Kinbiniola								
2			4	1075-1119	end	sec.	3⅜	9
7			1	897- 942	end	sec.	1½	10
8			4	1056-1124	end	sec.	3⅛	9
17			1	898- 941	end	sec.	1½	8
18			1	913- 941	end	sec.	1⅜	9
21			1	910- 943	end	sec.	1½	9
Peñasco Blanco								
1			?	773- 996	far	sec.	4¾	10
2			S 3	977-1061	end	sec.	2	8
3			S 3	1027-1061	end	sec.	1⅞	9
4			S 3	1009-1060	end	sec.	2	10
5			S 3	1004-1062	end	sec.	2	8
6			S 3	965-1061	end	sec.	3⅞	10
8			1	901- 940	end	sec.	1½	9
10			S 3	998-1051	end	½ sec.	3⅞	9
13	(repair logs)		1	927-1055	end	½ sec.	5⅞	8
15			1	914- 943	end	sec.	1½	8
21			1	860- 916	end	sec.	1¼	9
23			1	871- 915	end	sec.	1⅛	9
24			1	850- 898	end	sec.	1	9
25			1	861- 898	end	sec.	1⅞	8

Specimen number	Room	Floor Masonry	Date Inner-Outer	From end	Type	Radius in inches	Certainty
Pueblo Pintado							
3		S 3	1016-1060	end	core	3⅛	8
4		S 3	1009-1060	end	broken sec.	3⅞	8—
Tsinklitsin							
1		4	1040-1111	end	broken sec.	4½	9
2		4	1075-1111	end	sec.	2⅝	10
Una Vida							
(re-used)		4	947- 987	end	broken sec.	2⅝	8
3		1	904- 950	end	sec.	2⅜	8
7		1	904- 950	end	sec.	1⅝	9
8		1	897- 950	end	sec.	1⅝	9
12		1	895- 945	1- 5	sec.	1 9/16	9
18 b		1	895- 945	end	sec.	1⅞	9
20		1	821- 847	5-20	sec.	1¼	8—
24 (juniper)		S 3	884-1048	10-30	sec.	6	10

PROTOCOL 2

DATED CHARCOAL FROM EAST DUMP STRATA*

Stratum 4 East Trench

Specimen No.	Location Sec.	Lev.	Date of last ring present	Certainty	Radius	Wood
427	5	5	877- 939 A. D.	8	1¼	Piñon
413	8	6	910- 973	9+	1½	"
412	8	6	886- 960	9	⅞	"
445	6	8	871- 923	8	⅝	"
453	7	8	875- 933	8+	¾	"
434	1	9	895- 965	9	½	"
440	6	9	840- 932	8+	13/16	"
447	1	9	884- 932	8	7/16	"
448	7	9	844- 921	8+	9/16	"
233	5	9	ca. 1010-1054	8	1	"
			Stratum 3 West Trench			
244	6	13	970-1047	8	⅞	"
227	5	17	996-1037	8	⅞	"
228	5	18	975-1084 (1090)	9	⅝	"
239	6	18	988-1039	8	⅝	"
			West Central Pit			
260	2	2	933-1077	8+	⅞	"
280		2	994-1058	9	¾	"
203		2	994-1055	8+	⅞	"
282		2	979-1049	8	⅝	"
281		2	990-1044	8	½	"
254		3	939-1050	8	⅞	"
261		3	991-1047	9	¾	"
214		9	958- 942	8	⅞	"
265		26	975-1067 (1090)	8	½	"
			East Trench			
463	9	8	847- 945	8	⅝	"
446	6	8	884- 934	8	½	"

*The above specimens are arranged not in series but according to descending dates in descending levels. All dates represent last ring present, and must be corrected for burned-off exterior rings. Underlined dates are those nearest the deposition date in each stratum; dates in parentheses give those last dates as corrected for burned-off exteriors, and hence indicate the approximate year of strata deposition.

Specimen No.	Location Sec.	Location Lev.	Date of last ring present	Certainty	Radius	Wood
466	9	8	972- 929	8+	½	Pine
488	4	11	1011-1099 (1119)	8	1¼	Piñon
481	5	11	983-1081	9+	1	"
479	8	11	983-1075	8+	1¼	"
469	8	11	1006-1050	9	11/16	"
452	5	11	985-1050	8+	⅞	"
433	7	11	958-1009	9	1¼	"
461	7	12	1032-1064	8	¾	"
458	6	12	858- 930	9	9/16	"
460	6	13	1002-1048	8	5/16	"
407	4	14	1025-1071	10	1 5/16	Pine
406	4	14	1008-1045	8	1	Piñon
405	5	14	983-1006	8	1⅜	"
464	8	15	1017-1106 (1110)	8	⅝	"
465	8	15	979-1067	9	⅞	"
414	7	15	1001-1066	8	½	"
417	7	15	889- 933	8	⅝	"
408	6	16	960-1047	10	1 5/16	"
430	5	16	870- 938	9	⅞	"
402	4	17	1053-1105	8+	¾	"
507	5	20	990-1090	8	⅝	"
508	5	20	998-1063	8	1	"
500	5	21	1001-1091	8+	¾	"
497	5	23	953-1064	8	¾	"
496	5	23	950-1060	8	¾	"
505	5	24	1013-1065	8	½	"
504	5	24	1003-1054	8	¾	"
511	5	26	1026-1051	8	⅝	Douglas fir
493	5	26	1002-1048	8	½	Piñon
			Stratum 2			
490	5	27	948-1060 (1090)	9+	⅞	"

TABLE OF SHERDS, EAST AND WEST TRENCH, EAST DUMP

	Total	% based on Total	% based on Black and White Types as 100
Total sherds	45308	100 %	
Total black on white	23153		
Total corrugated	19539		
Total polished black on white	10252		
Total semi-polished black on white	9648		
Total unpolished black on white	3253		
Total fine corrugated	5299		
Total medium corrugated	12127		
Total coarse corrugated	1813		
Polished black on white			
St. 4	1135	16.2	28.4
St. 3	7537	27.3	55.0
St. 2	1441	14.0	28.0
St. 1	139	33.2	51.1
Semi-polished black on white			
St. 4	2156	33.5	54.0
St. 3	4674	16.9	34.0
St. 2	2725	26.5	50.9
St. 1	93	22.2	34.2
Unpolished black on white			
St. 4	692	9.9	17.3
St. 3	1518	5.5	11.0
St. 2	1003	9.8	19.4
St. 1	40	9.5	14.7
Corrugated fine			
St. 4	1303	18.6	33.8
St. 3	2681	9.7	18.8
St. 2	1481	14.4	28.6
St. 1	82	19.5	30.2
Corrugated medium			
St. 4	1440	20.6	36.2
St. 3	8650	36.5	63.0
St. 2	2270	22.0	44.0
St. 1	61	14.5	22.4
Corrugated coarse			
St. 4	171	2.4	4.3
St. 3	789	2.9	5.8
St. 2	853	8.3	16.5
St. 1	0	0	0

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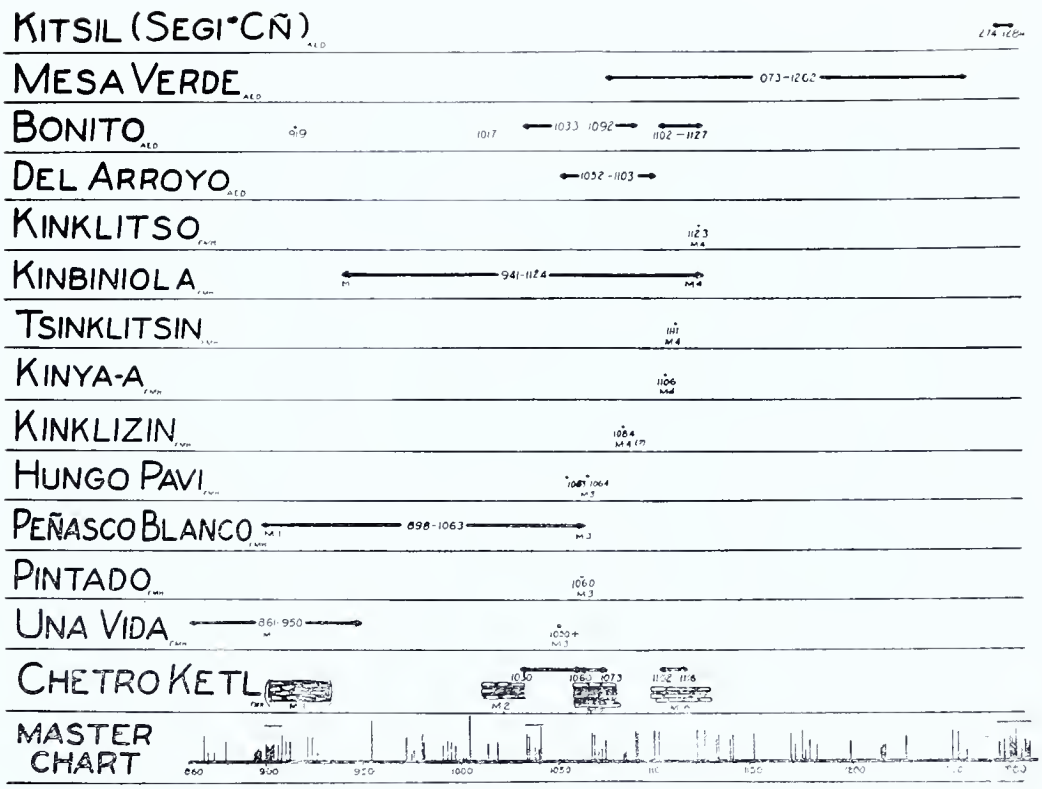
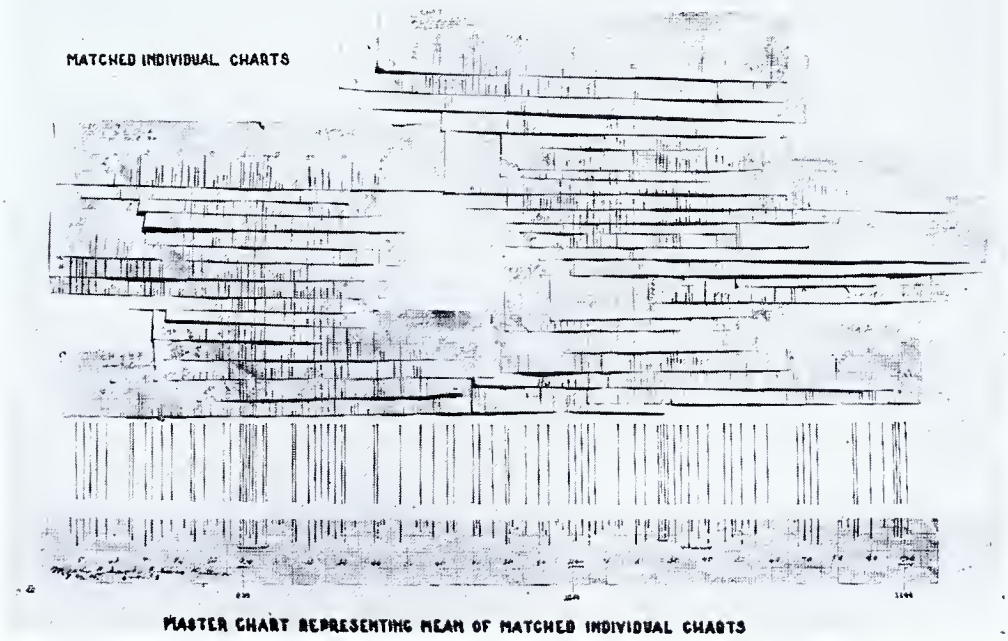
Plates

PLATE I



SUPPLEMENTARY CHACO (PIÑON) MASTER CHART

DEVELOPED BY CROSS-IDENTIFYING SPECIMENS



MASTER CHART REPRESENTING MEAN OF MATCHED INDIVIDUAL CHARTS

PLATE II

PUEBLO DEL ARROYO AND SOUTH GAP OF THE CHACO

YELLOW HOUSE, SEEN FROM THE NORTH CLIFFS

PLATE III

1.

2.

3.

4.

1. Barren Chaco landscape.
2. Sandstone cliffs behind Pueblo Bonito.
3. Great Sanctuary, Chetro Ketl.
4. Ceiling beams, Kiva K, 1099 A. D., Chetro Ketl.

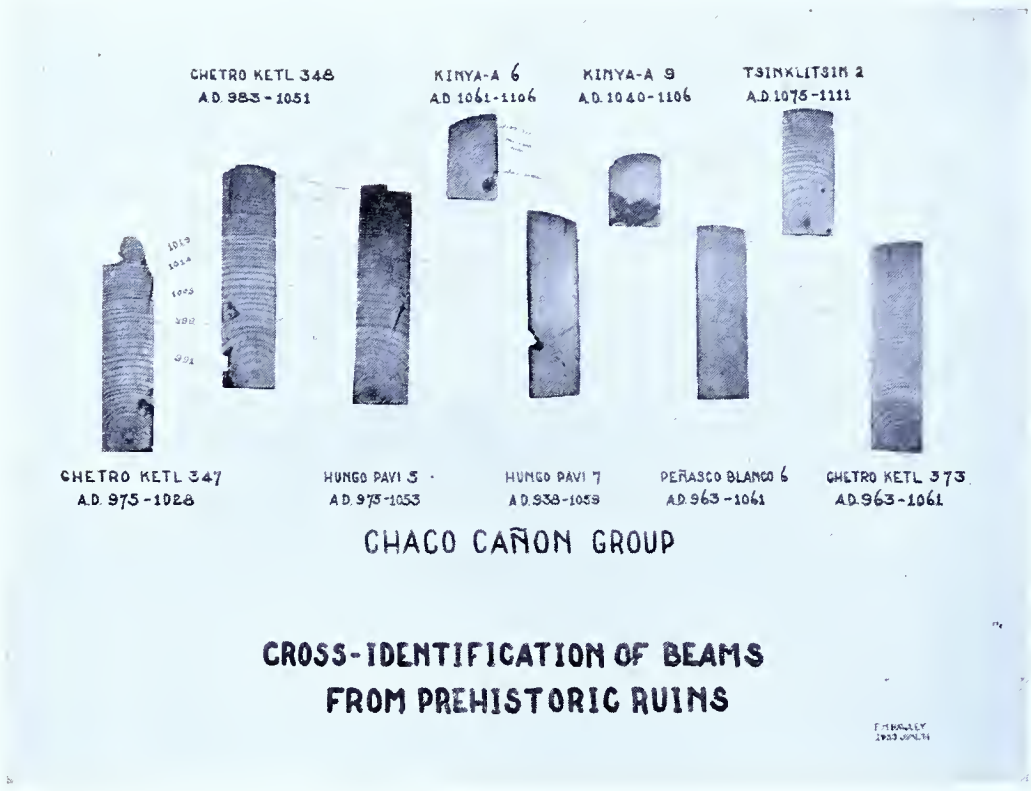
Plate IV

Chaco Masonry Types

1. Type I, Una Vida.
2. Type III over Type II, back wall of Chetro Ketl.
3. Type II, detail, Chetro Ketl.
4. Superior Type III, detail, Chetro Ketl.

CHACO MASONRY TYPES

1. Type VI bench, superposed over inferior Type III, Great Sanctuary, C. K. (Note crude banding of inferior Type III.)
2. Type IV, Pueblo Alto. Identical with Type IV, Chetro Ketl.
3. Detail of variation of Type IV at Kinya-a, 1106 A. D.
4. Type V superposed over Type II, east wall, Chetro Ketl.



Cross identification of beams from prehistoric Chaco ruins.

End of prehistoric beam showing crushed fibers characteristic of stone axe cuts.

C. K. 373, pine. (936-1061 A. D.)

U. V. 24, juniper. (884-1048 A. D.

C. K. 331, mounted section of pine pilaster support from Kiva G. The outer date present is 953 A. D.; approximately 150 rings have decayed away from the exterior. When this specimen was dated in 1933, its inner sequence was found to end at 643 A. D., in the center, thus carrying the prehistoric climatic record almost 100 years farther into the past than previously had been known with certainty.

Plate IX

1.

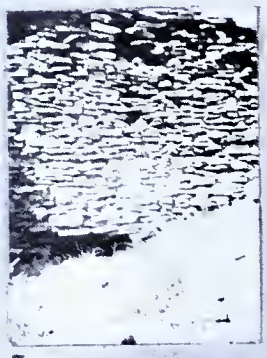
2.

3.

4.

5.

6.



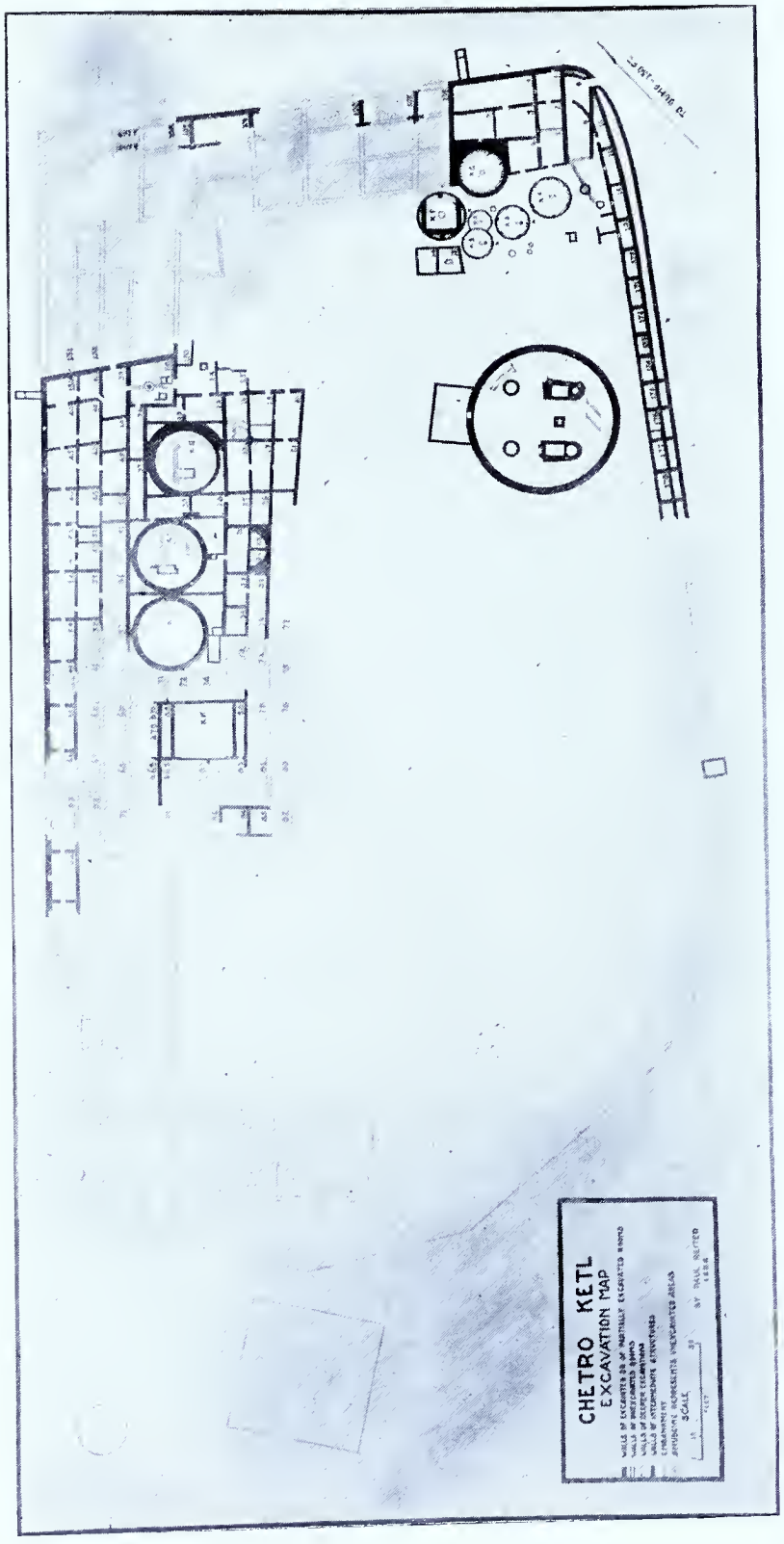
7.

8.

9.

1. Starting plate nailed to beam to be bored.
2. Boring the beam.
3. Removing the core, a radius of the log.
4. Modern forest border near Continental Divide west of Cuba, showing retreat of trees such as probably occurred in past centuries at the head of the Chaco.
5. Masonry III superposed over Masonry I, Una Vida.
6. Kiva pilaster support, C. K. 331, *in situ* on bench of Kiva G. Dates: 643-953+ca. 150, or 1103.
7. Una Vida wall of Masonry I, containing earliest log yet dated in the Chaco, 864 A. D.
8. Large beam dated 1060 A. D., room 48, Masonry II, Chetro Ketl.
9. Room 24, Masonry IV, containing as a repair beam the latest log yet dated in Chetro Ketl—1116 A. D.

PLATE X



MAP OF CHETRO KETL

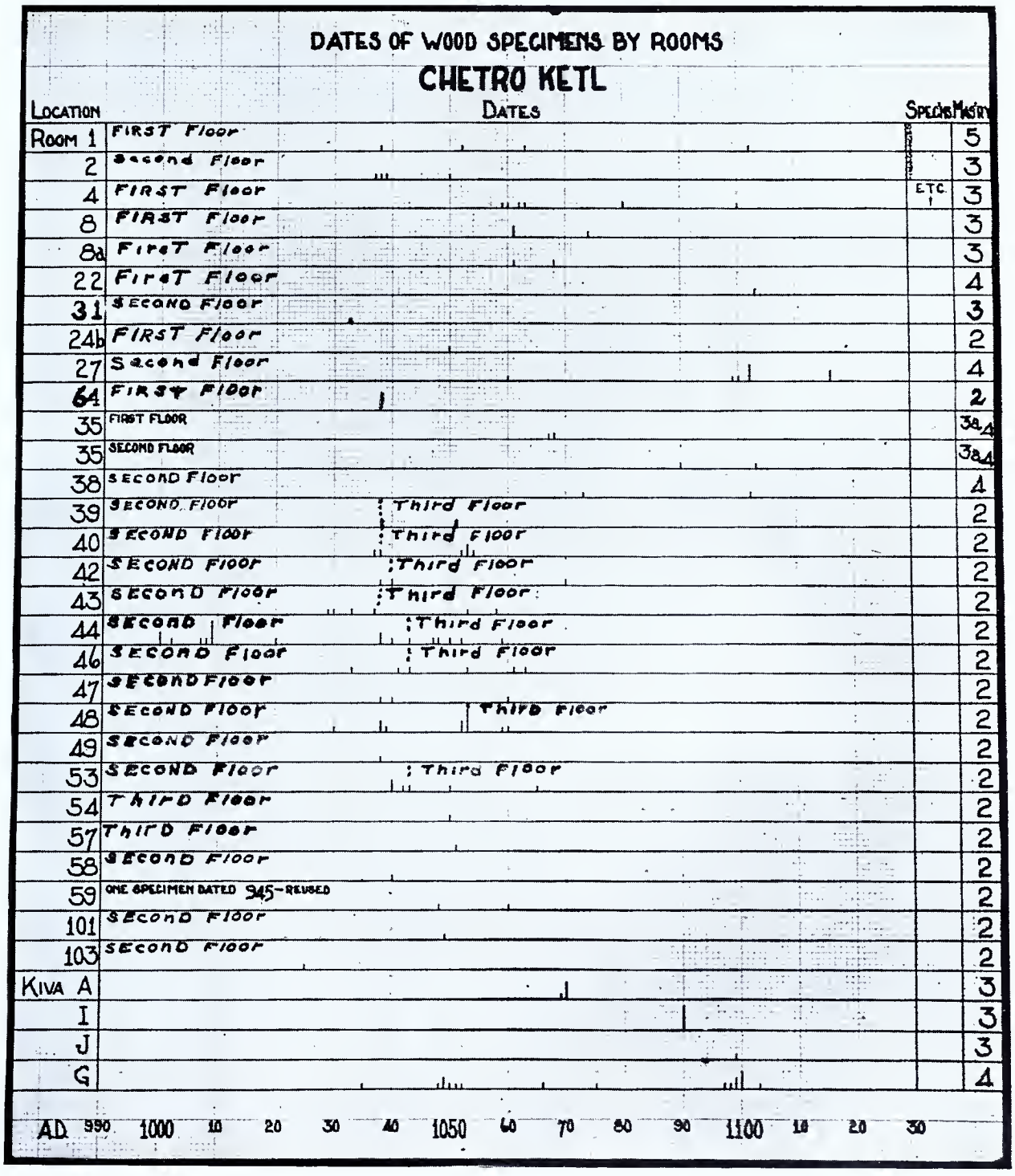
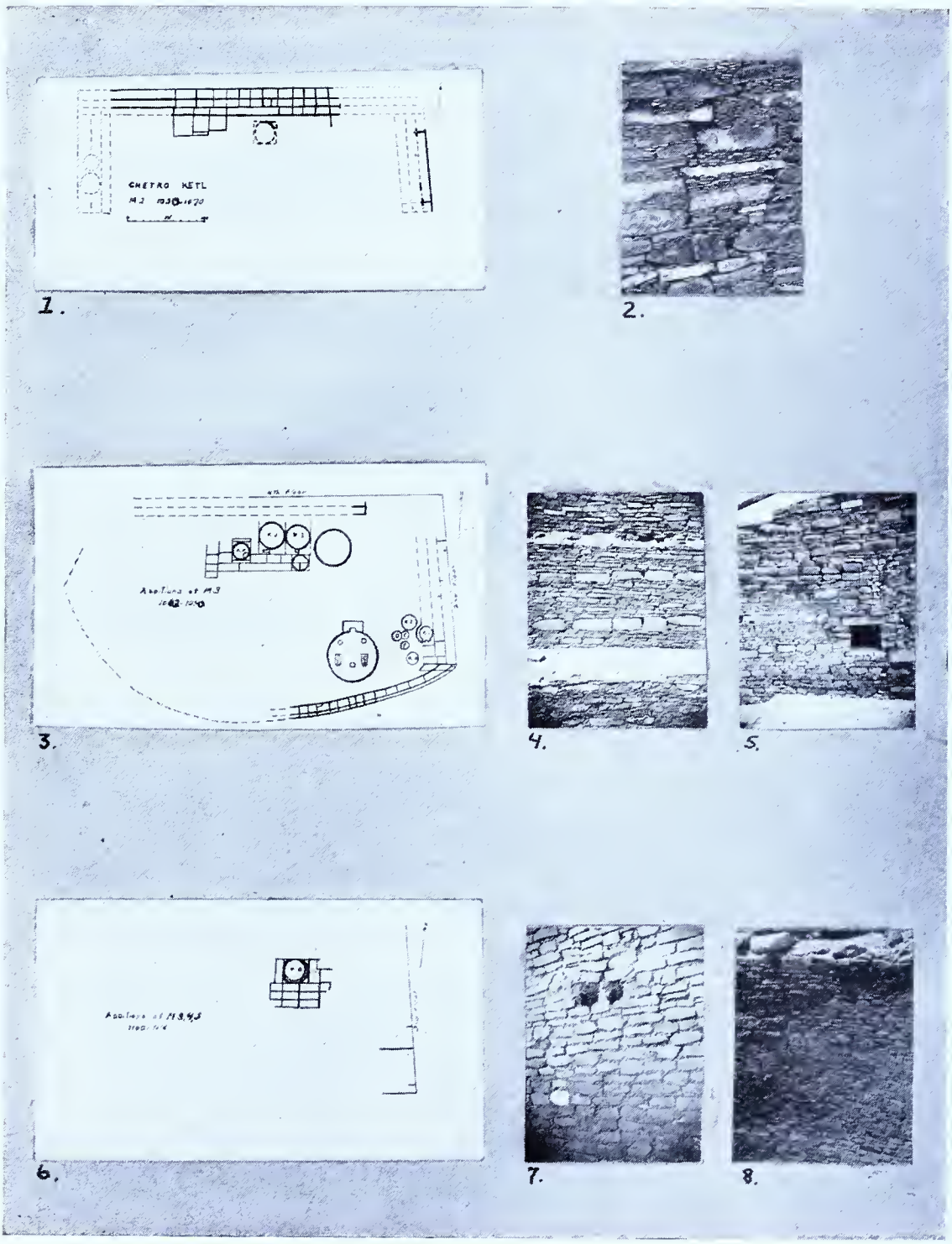

DATES OF WOOD SPECIMENS BY ROOMS
CHETRO KETL
LOCATION
DATES
SPECIMENS
MASTER
Room 1 FIRST Floor 5
2 Second Floor 3
4 FIRST Floor ETC. 3
8 FIRST Floor 3
8a FIRST Floor 3
22 FIRST Floor 4
31 SECOND Floor 3
24b FIRST Floor 2
27 Second Floor 4
64 FIRST Floor 2
35 FIRST FLOOR 3a4
35 SECOND FLOOR 3a4
38 SECOND Floor 4
39 SECOND FLOOR Third Floor 2
40 SECOND FLOOR Third Floor 2
42 SECOND FLOOR Third Floor 2
43 SECOND Floor Third Floor 2
44 SECOND Floor Third Floor 2
46 SECOND Floor Third Floor 2
47 SECOND Floor 2
48 SECOND Floor Third Floor 2
49 SECOND Floor 2
53 SECOND Floor Third Floor 2
54 THIRD Floor 2
57 THIRD Floor 2
58 SECOND Floor 2
59 ONE SPECIMEN DATED 945-REUSED 2
101 SECOND Floor 2
103 SECOND Floor 2
KIVA A 3
I 3
J 3
G 4
AD 990 1000 10 20 30 40 1050 60 70 80 90 1100 10 20 30

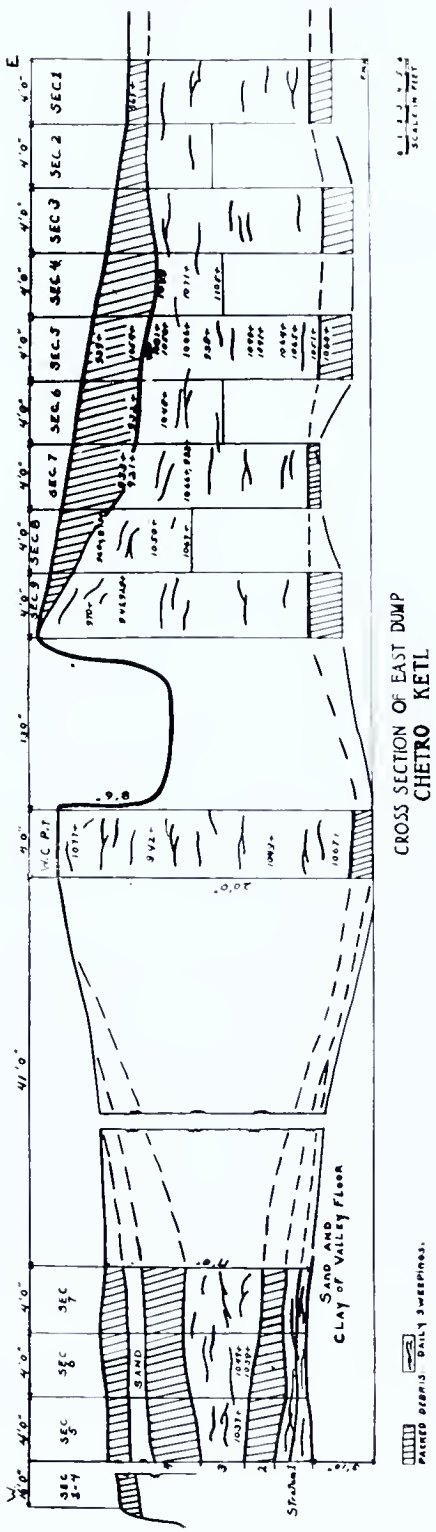
Plate XII



Masonry and Building Periods at Chetro Ketl

1. Second period of construction. A—(1030-1070).
2. Type II.
3. Second period of construction. B—(1062-1090).
4. Type III. Superior.
5. Inferior.
6. Third period of construction. (1100-1116+).
7. Type IV.
8. Type V.

PLATE XIII



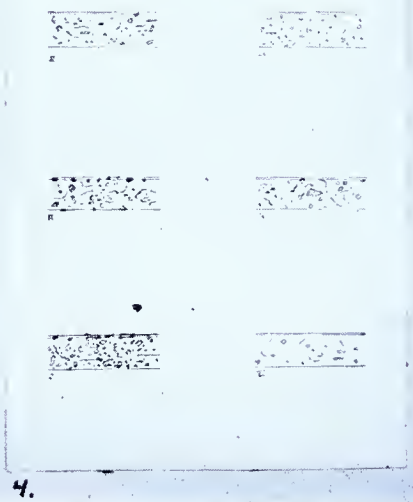
CROSS SECTION OF EAST DUMP
CHETRO KETL

Plate XIV

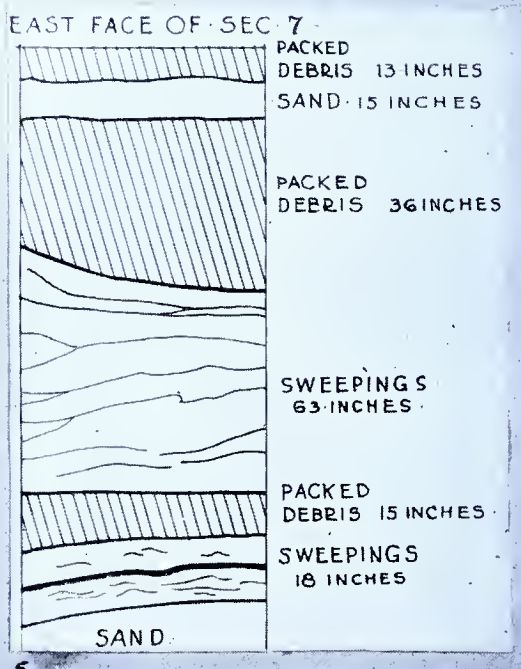
1.

2.

3.



4.



5.

1. East dump as trench is started on east side.
2. East trench, showing alternate pits.
3. Burial in dump.
4. Cross section of walls of pottery types.
5. East face of Sec. 7, West trench.

POTTERY TYPES FOUND AT CHETRO KETL

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